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THE FACTOR CONTENT OF TRADE WITH UNEQUAL FACTOR PRICES

by

Eunjoong Kang

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of

Doctor of Philosophy
Department of Economics

Carleton University
Ottawa, Ontario
December, 1991

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The Faculty of Graduate Studies and Research
acceptance of the thesis,

"The Factor Content of Trade with Unequal Factor Prices"

submitted by

Eun-Joong Kang, B.A., M.A.

in partial fulfilment of the requirements
for the degree of Doctor of Philosophy.

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Abstract

The Factor Content of Trade with Unequal Factor Price

Eunjoong Kang

Carleton University, 1991

Leamer's reconsideration of the Leontief paradox has stimulated extensive empirical testing of the Heckscher-Ohlin-Vanek model -- that is, a multifactor version of the Heckscher-Ohlin model with factor price equalization everywhere. There is now a considerable evidence that there exist major departures from this model. One reason for the failure of the Heckscher-Ohlin-Vanek model may simply be that factor prices are not equalized due to trade barriers and/or large differences in factor endowments between countries. The paper explores this possibility by extending and implementing tests of the factor content version of the Heckscher-Ohlin model with unequal factor prices.

The paper is divided into two parts: In the theoretical part, I first consider Helpman's factor content version of the HO theorem in a model which allows for the presence of intermediate goods. In this model, an important issue is whether the calculation of factor contents should be based on only direct or gross (direct-plus-indirect) factor requirements. Next I show that, when trade in goods (including intermediate goods) is subject to trade barriers, neither direct nor gross requirements are relevant to explaining the factor content of trade. I then develop a new measurement which is referred to as "home-gross" factor requirements. I establish that the home-gross requirements always provide a valid measure of factor content of trade.

In the empirical part of this study, I first develop the test in a form that can be implemented empirically. Next I apply this test to three pairs of countries; the US and Canada, the US and the UK, and the US and Japan. I find, for all three of these pairs, that estimates of factor content of trade in goods differ significantly from predicted values.

Acknowledgments

I would like to express my deep gratitude to professor Ehsan U. Choudhri, my thesis supervisor, who has provided invaluable suggestions and guidance through all stages of this thesis. He also has inspired me to develop and apply my analytical abilities with confidence. I would like to thank professors Richard Brecher and Larry Schembri, who have spent their valuable time reading the manuscript and provided many insightful comments.

I also wish to extend thanks to professor Soobin Park for his personal support and encouragement. I am grateful to professor R. F. Neil for a fast and tolerant proof-reading. Special appreciation is due to professor Hyongwoo Lee of the Department of Systems and Computer for helping me overcome the numerous computing problems with care.

Any remaining shortcomings of this work are the sole responsibility of the author.

Finally, heartfelt thanks go to my wife, Hyangseon, for her love, patience, and understanding during the course of this endeavor. Also appreciated was her labour and continued support in typing the manuscript through repeated revisions. Without her this thesis would never have been completed.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

I.1 Purpose of the Study

The empirical inadequacy of the Heckscher-Ohlin-Vanek (HOV) model of international trade has been an issue of contention at least since the Leontief paradox. Recently interest in this issue has been stimulated by Leamer's (1980) explication that Leontief's (1954) celebrated results are not really inconsistent with a multifactor version of the Heckscher-Ohlin (HO) theorem with factor price equalization everywhere. Despite the abundance of literature purporting to test it in some fashion, however, empirical results have continued to solidify the evidence of major departures from this model and thus to cast doubt on the overall validity and usefulness of the Heckscher-Ohlin theorem.¹

One reason for the failure of the Heckscher-Ohlin-Vanek model may simply be that factor prices are not equalized due to the protection afforded by trade barriers and/or large differences in factor endowments

¹ See, for instance, Brecher and Choudhri (1982b, 1988), Maskus (1985), Staiger, Deardorff and Stern (1987), and Bowen, Leamer and Sveikauskas (1987).

between countries. The purpose of this paper is to explore this possibility by extending and implementing tests of the factor content version of the Heckscher-Ohlin model with unequal factor prices.

Helpman (1984a) has recently derived restrictions on the factor content of bilateral trade patterns as functions of differences in factor prices, which can be tested with post-trade data. The only assumptions required for his test are that two countries have the same constant-returns-to-scale technology, perfect competition, and free trade. As intermediate goods are not explicitly considered in his model, though, one potential problem with the test is how to empirically measure the factor content of the traded goods.

Staiger (1986) has extended Helpman's analysis to a world of freely traded intermediate goods, and shown that direct factor requirements should be used to measure factor content. However, if intermediate goods are exchanged subject to trade barriers, then direct requirements do not necessarily provide a valid measure of factor content. One objective of this paper is to develop the theoretically appropriate measure of factor content for use in empirical examination of the Heckscher-Ohlin predictions. We will refer to this measure as the "home-gross" factor requirements. As these tests have not yet been implemented empirically, the other objective of this paper is to implement the test in a multifactor model exploiting the

implications of cost minimization so that we can examine the Heckscher-Ohlin theorem's empirical validity in the economies with unequal factor prices. We restrict our test of the factor content pattern of bilateral trade to four countries: the United States, Canada, the United Kingdom, and Japan for which both their characteristics and availability of data are comparable with our model. We take the United States and Canada to have similar factor endowments. The United States and Japan, and the United States and the United Kingdom are taken as two country pairs with different endowments. Test results in the three cases are compared.

If our test is not failed, we would conclude that the rejection of the factor content version of the Heckscher-Ohlin model arises from the inappropriate assumption of factor price equalization (and thus that of free trade). On the other hand, a failure of the test would point out that factor price differences alone, given trade barriers, do not account for discrepancies between the factor content of the observed pattern of trade and that predicted by the Heckscher-Ohlin-Vanek theorem. Such a result would suggest that a more promising approach might be based on specific departures from the basic assumptions of the Heckscher-Ohlin-Vanek model regarding technology and market structure.

1.2 Survey of Previous Literature

A. Factor Content Version of the Heckscher-Ohlin Theorem

We begin this section by reviewing the Heckscher-Ohlin theorem in its "factor content" version [i.e. the Heckscher-Ohlin-Vanek model].² The standard Heckscher-Ohlin-Vanek model has the following features:

- (1) production functions are the same in all countries and exhibit constant returns to scale
- (2) tastes are homogeneous and identical in all countries
- (3) there is perfect competition in factor as well as commodity markets
- (4) there is free international trade
- (5) factor prices are equalized across countries.

Given the basic Heckscher-Ohlin-Vanek assumptions, it follows that

$$(1.1) \quad V = AX$$

$$(1.2) \quad V^W = AX^W$$

$$(1.3) \quad V_c = AC$$

where V denotes the vector of factor endowments for a country;

V^W the vector of the world endowments of factors;

² The HO theorem has been stated in two forms: "commodity content" version and "factor content" version. The commodity content version of the HO theorem has been somewhat difficult to prove with any generality as a theoretical proposition. If there are more goods than factors, then the pattern of commodity trade is not uniquely determined. However, the factor content of net trade flows is uniquely determined (See Travis 1964, Melvin 1968, and Vanek 1968). As a result, this has led to measurement of the factor content of trade as a means of testing the HO theorem empirically.

- C the vector of the country's consumption (expenditure);
- V_c the vector of factors embodied in the country's consumption flows;
- X the vector of the country's outputs;
- X^W the vector of total world outputs; and
- $A = \{ a_{ij} \}$ the technique matrix shared by all countries whose elements are the gross (direct plus indirect) requirements of factor i used in producing one unit of good j .

Since the relative prices of goods are equalized through international trade for all countries, the identical homothetic taste patterns imply that each country consumes commodities in the same proportions:

$$(1.4a) \quad C = \alpha X^W$$

or

$$(1.4b) \quad C = \alpha C^W$$

where α is a scalar representing the country's share of world expenditure and C^W is the vector of total world consumption (expenditure).³ From equations (1.2) through (1.4a) we write the factor content of consumption as a function of total world endowments:

$$(1.5) \quad V_c = \alpha V^W$$

³ Note that underlying assumption of equation (1.4) is that world consumptions equals world outputs.

Since consumption equals output plus imports minus exports, V_c can also be written as

$$(1.6) \quad V_c = V + (V_M - V_X)$$

where V_M and V_X are the vectors of factor contents of imports and exports respectively. If V_T represents the vector of factors embodied in the country's net commodity trade such that $V_T = V_X - V_M$, then equation (1.6) can be rewritten as

$$(1.7) \quad V_T = V - V_c$$

Substituting equation (1.5) into equation (1.7) we obtain the basic Heckscher-Ohlin-Vanek relationship for the factor content of net trade as

$$(1.8) \quad V_T = V - \alpha V^W$$

meaning that the factors embodied in net commodity trade equal the excess factor supplies.

The Heckscher-Ohlin-Vanek equation (1.8) can be served to reveal the country's relative factor abundance. For any two factors, say K and L , equation (1.8) gives

$$(1.9a) \quad K_T = K - \alpha K^W$$

$$(1.9b) \quad L_T = L - \alpha L^W$$

where K_T and L_T are capital and labour services embodied

in net exports, K and L are the factor endowments of the country in question, K^w and L^w are the world's factor endowments. These two equations can be manipulated to derive the condition under which trade reveals the country to be capital abundant relative to labour, $\frac{K}{K^w} > \frac{L}{L^w}$, if and only if ⁴

$$(1.10) \quad \frac{K_T}{K} > \frac{L_T}{L}$$

We also know from equation (1.8) that

$$(1.11a) \quad K_T \begin{matrix} \geq \\ < \end{matrix} 0 \quad \text{as} \quad \frac{K}{K^w} \begin{matrix} \geq \\ < \end{matrix} \alpha$$

$$(1.11b) \quad L_T \begin{matrix} \leq \\ > \end{matrix} 0 \quad \text{as} \quad \frac{L}{L^w} \begin{matrix} \leq \\ > \end{matrix} \alpha$$

If trade is assumed to be balanced, so that each country's expenditure equals its income at factor cost, then α is the country's share of world income implying⁵

⁴ Equation (1.9) can be written as $K_T/K = 1 - (\alpha K^w/K)$ and $L_T/L = 1 - (\alpha L^w/L)$. Substituting these into equation (1.10) yields $K/K^w > L/L^w$. As noted by Leamer (1980) equation (1.10) does not rule out the possibility that a country could be a net exporter of both capital and labour.

⁵ If trade is balanced, α can be written as a weighted average of K/K^w and L/L^w ;

$$\begin{aligned} \alpha &= (WL + RK) / (WL^w + RK^w) \\ &= WL / (WL^w + RK^w) + RK / (WL^w + RK^w) \\ &= (L/L^w) \left[WL^w / (WL^w + RK^w) \right] + (K/K^w) \left[RK^w / (WL^w + RK^w) \right] \\ &= (L/L^w) S_L^w + (K/K^w) S_K^w \end{aligned}$$

where W is the wage rate for labour, R is the rental

$$(1.12) \quad \frac{K}{K^W} > \alpha > \frac{L}{L^W}$$

The combination of equations (1.11) and (1.12) yields the Vanek (1968) - Melvin (1968) proposition that

$$(1.13) \quad K_T > 0 > L_T$$

It follows that a country will be a net exporter of services of those factors with which it is relatively well endowed and a net importer of services of those factors with which it is relatively poorly endowed. This is a general statement of the factor content version of the Heckscher-Ohlin theorem in the presence of factor price equalization.⁶

For the special case of two factors Brecher and Choudhri (1982a) extend this proposition elegantly to the case where there is no factor price equalization.⁷ A two-factor, three-good, and two-country case is depicted at Figure 1.1 which was originally developed by Brecher and Choudhri (1982a, the rays representing overall capital/labour ratios are added). The unit-value isoquants

rate for capital, S_L^W and S_K^W are the distributive shares of labour and capital in world income, respectively. Thus, α must lie between (L/L^W) and (K/K^W) .

⁶ The commodity content version, however, is known to be fragile where international factor price equalization occurred. See Bhagwati (1972).

⁷ For the commodity content version Deardorff (1979) provides a formal proof which this proposition holds in the absence of international factor price equalization.

Figure 1.1
Case of $2 \times 3 \times 2$

each describes one dollar's worth of output (that is, the unit-value isoquant i represents the output level $1/p_i$, where p_i is the price of good i). For each country the ray K/L (K^*/L^*) represents the capital/labour ratio of its endowment, and the downward sloping line with slope w_L/w_K (w_L^*/w_K^*) represents its unit-cost line corresponding to one dollar's worth of inputs for the country. The factor input coefficients (a_K , a_L , a_K^* , and a_L^*) are given by the points where unit-value isoquants are tangent to unit-cost lines; a_{ki} (a_{ki}^*), for example, denotes the quantity of capital (labour) required by the capital (labour) abundant country to produce one dollar's worth of commodity i . Thus, it is clear from the figure that

$$(1.14) \quad a_{ki} - a_{kj}^* > 0 > a_{li} - a_{lj}^*$$

where i belongs to the set of all goods exported and j the set of all goods imported by the capital abundant country respectively. It follows directly from equation (1.14) that one dollar's worth of any commodity exported by the capital abundant country uses more capital and less labour than one dollar's worth of any commodity exported by the labour abundant country, thereby establishing the factor content version of the Heckscher-Ohlin theorem in the absence of factor price equalization.

Helpman (1984a), in an important contribution, shows that the factor content theorem also holds for the many good, many factor case in the presence of unequal factor

prices. Helpman's proposition is fully discussed in Chapter II.

B. Review of Empirical Work

There are two major approaches to testing the Heckscher-Ohlin model statistically. The first approach is to test the underlying assumptions⁸, whereas a second approach is to test implications or predictions arising from the model. The second approach to evaluating the Heckscher-Ohlin model has usually taken one of two forms: Leontief-type factor content analysis and cross-section regression analysis.

The Heckscher-Ohlin-Vanek model implied by equation(1.8) is a relation involving net exports, factor input requirements and factor endowments. It has been argued convincingly by Leamer (1980), Leamer and Bowen (1981), and Deardorff (1984) that a conceptually complete test of the theorem must include data on all three sets of these variables. Most studies testing the theorem, however, have computed only two of the three variables and have inferred the third under the Heckscher-Ohlin-Vanek assumptions.

⁸ Hunter and Markusen (1988), for example, examine the assumption of identical homothetic tastes over thirty four countries and show strong evidence to reject this hypothesis. Instead, Dollar, Wolff and Baumol (1988) are concerned with factor price equalization (FPE) and implications from it. If FPE holds, then industries should have the same labour productivity across countries. This hypothesis is tested across thirteen OECD countries and is rejected.

Factor content analyses such as Leontief (1954) use measures of factor input requirements A and net exports T (that is, $V_T = AT$) and from them infer the factor abundance vector $V = \alpha V^H$. Cross-section regression analyses such as Baldwin (1971) and Stern and Maskus (1981) also take measures of factor input requirements A and net exports T to infer the factor abundance $V = \alpha V^H$, while analyses such as Leamer (1974, 1984) and Bowen (1983) use measures of net exports T and factor endowments V and implicitly infer the factor input requirements A . These types of analyses can not be said to be a logically complete test of the Heckscher-Ohlin-Vanek theorem because those use measures of only two of the three variables.⁹

Some previous the Leontief-type tests of the Heckscher-Ohlin-Vanek model are briefly reviewed in the rest of this section. The classic test of the factor content of trade was conducted by Leontief (1954). He used 1947 input-output table and trade data for the U.S. economy to measure the capital and labour embodied in representative bundles of U.S. exports and import substitutes and found

⁹ Exceptions are Maskus (1985), Bowen, Leamer and Sveikauskas (1987). Both of these papers provide a conceptually correct test of the HO theorem which requires independent measures of a country's trade, its factor intensities in production, and factor endowments of the country. Harkness (1978, 1983) also provides a proper test, requiring data on all of three variables, but he inappropriately correlates factor endowments with the regression coefficients of trade on factor intensities, as pointed out in Leamer and Bowen (1981). For a list of studies, which calculate only two of the three concepts, see Leamer (1984) and Deardorff (1984).

more labour in exports than in imports and more capital in imports than in exports.¹⁰ If trade were balanced, we would derive from equation (1.8) that the United States' share of world's labour endowments must be greater than its share of world's capital endowments [that is, $L/L^W > K/K^W$ in relation to equation (1.10)]. Since the United States is commonly supposed to be capital abundant and labour-scarce relative to the rest of the world, Leontief's classic result led to a refutation of the Heckscher-Ohlin theorem. Subsequently a number of studies have examined the empirical proposition to resolve this so called "Leontief paradox".¹¹

Important progress in this area has been made recently by Leamer (1980) who argues that the Leontief paradox is based on a simple conceptual misunderstanding, because the Heckscher-Ohlin model in its multifactor version does not imply that a capital abundant country must have its export bundle more capital intensive than its bundle of imports. Instead Leamer demonstrates that if a country's trade embodies a net export of both labor and capital services (as was the case for the U.S. in Leontief's data), then the proper comparison is the factor ratios embodied in net exports versus consumption, rather than the factor ratios embodied in exports versus imports.

¹⁰ These calculations of the factor contents of imports and exports are inappropriate for inferring revealed abundance rankings in the multifactor context, as shown in Leamer (1980).

¹¹ See Stern (1975) and Deardorff (1984) for the surveys on these issues of the Leontief paradox.

Equation (1.8) can also be used to rewrite equation (1.10) as

$$(1.15) \quad -KL_T > -LK_T$$

Since $K = K_C + K_T$ and $L = L_C + L_T$ in view of equation (1.7), equation (1.15) implies that

$$(1.16) \quad -K_C L_T > -L_C K_T$$

If L_T and K_T are both positive, then equation (1.16) reduces to

$$(1.17) \quad \frac{K_T}{L_T} > \frac{K_C}{L_C}$$

Thus a country that is an exporter of both labour services and capital services is revealed by trade to be relatively capital abundant if capital per worker is greater in net exports than in consumption. He shows, according to this criterion, that the United States is actually revealed by trade to be capital abundant, so that the Leontief paradox disappears.¹²

Brecher and Choudhri (1982b), however, argue that such

¹² Stern and Maskus (1981) also compare the capital/labour ratio in net exports with the capital/labour ratio in consumption for the U.S. and find that the revealed abundance ordering in 1958 is human capital > labour > physical capital, and in 1972 is physical capital > human capital > labour. Thus the calculations for the US uphold the Leontief paradox for 1958, but not for 1972. However, the latter result (for 1972) is also overturned in Maskus' later research (1985).

a test fails at least for labour in Leontief's (1954) data. They demonstrate, by applying equation (1.8) to labour, that a country can be a net exporter of labour services only if its expenditure per worker is less than in the rest of the world.

From equation (1.8), trade in labour services can be written as

$$(1.18) \quad L_T = L \left(1 - \frac{\alpha L^W}{L} \right)$$

Equations (1.4b) and (1.18) implies that

$$(1.19) \quad L_T > 0 \quad \text{if and only if} \quad \frac{C}{L} < \frac{C^W}{L^W}$$

Given the evidence, which shows that expenditure per worker was indeed greater in the United States than in the world as a whole and that United States trade embodied a net export of labour, Brecher and Choudhri point out that the United States was labour abundant relative to all other factors. This gives us the Leontief paradox again.

Maskus (1985) claims that most of uncertainty regarding the empirical validity of the Heckscher-Ohlin-Vanek theorem stems from the use of inappropriate testing techniques. Instead, by adopting more recent data, he provides a conceptually complete test of the theorem. This requires independent measures of trade, factor intensities and factor endowments both of the country in question and the rest of the world. Maskus actually tests three different version of Heckscher-Ohlin-Vanek prediction using 1958 and 1972 United

States data and finds that for all three cases United States data are shown to diverge largely from their values as predicted by the Heckscher-Ohlin-Vanek theorem, thus reaffirming the Leontief paradox.

Another conceptually complete evaluation of the Heckscher-Ohlin-Vanek theorem is performed more recently by Bowen, Leamer and Sveikauskas (1987) who test the theorem in both the Leontief type context and the regression context that allows technological differences and measurement errors in a multicountry, multifactor world. They compute the amount of each of twelve factors embodied in the net exports of twenty seven countries using the United States total input requirements for the year 1967, and then compare the factor contents of trade with direct measures of factor endowments to examine whether the data conform to the prediction of the Heckscher-Ohlin-Vanek model. Overall, their results reinforce the evidence of discrepancies between actual data and the prediction from the model, but also suggest that the poor performance of the Heckscher-Ohlin-Vanek hypothesis is related to measurement error in both trade and factor endowments across countries.¹³

It is an important empirical issue, as Travis (1964, 1972) and recently Deardorff (1979) have claimed, to explore whether protection can account for the discrepancies between

¹³ They approximate world factor endowments as the sum of the national factor endowments of those sample countries. They, however, find the evidence of measurement error when this measure of factor endowments is employed.

the observed pattern of trade and the pattern of trade predicted by the Heckscher-Ohlin-Vanek theorem. Staiger, Deardorff and Stern (1987) examine this issue by using the Michigan Model of World Protection and Trade to calculate the 1976 factor contents of trade for Japan and the United States in a hypothetical free trade world. Their idea is that if the latter conform to the predictions of the theorem more closely than do observed patterns of trade, then one might conclude that the presence of tariffs and non tariff barriers can account for large difference between predicted and observed trade patterns. Based on their calculations they show evidence of divergences between observed trade patterns and those predicted by the theorem. They also show, however, that elimination of trade barriers might worsen these divergences, thereby implying that the existing protection is not a key source of the divergences.¹⁴

Most recently, Brecher and Choudhri (1988) show that the Heckscher-Ohlin-Vanek model does not even hold for two countries: Canada and the United States, a pair of countries that may be reasonably thought to satisfy the basic assumptions of the model. According to the prediction of their well-specified version of the model, factor contents of a dollar's worth of domestic expenditure must be the same

¹⁴ As indicated by the paper, this test can not be said to be a complete evaluation of the issue (which require international trade, factor endowments, and factor input requirements data for all countries) because they examine data for simply two country sample of Japan and the United States.

in the two countries for all factors.¹⁵ This hypothesis is tested, by using an errors-in-variables framework, for fourteen factors for the years 1963, 1972 and 1979, and is rejected for a number of factors, especially among natural resources and labour.¹⁶

1.3 Dissertation Outline

There is now considerable evidence that there exist major departures from the Heckscher-Ohlin-Vanek model.¹⁷ It is reasonable to conclude, however, that the assumptions of the Heckscher-Ohlin-Vanek model are too restrictive for the theorem to hold in an empirical context, rather than that the evidence is sufficiently decisive to reject the theorem as a foundation of comparative advantage analysis. In view of this possibility this paper develops a factor content version of the model by modifying the Heckscher-Ohlin-Vanek assumptions of free trade and factor price equalization.

¹⁵ Given the basic HOV assumption, we can use equations (1.4b) and (1.3) to derive the following proposition for the two-country version of the model: $V_c^{CAN} = \beta V_c^{US}$, where β is a scalar and V_c^i is the factor content of consumption, based on the home input requirements of country i . Since $\beta = C^{CAN} / C^{US}$ in view of equation (1.4b), the above equation can be rewritten as $V_c^{CAN} / C^{CAN} = V_c^{US} / C^{US}$.

¹⁶ The HOV predictions are intended to apply to all trading countries of the world, and therefore the choice of these two countries does not allow for a complete test of the theorem.

¹⁷ There are some weak tests (Leamer 1980, 1984) with results that are favorable to the HOV model.

Our analysis of the factor content of trade is divided into two parts.

The theoretical part of this study is devoted to showing how the model may be extended in a number of directions to take account of different assumptions about the pattern of production and trade. In chapter II we extend Helpman's factor content test of the Heckscher-Ohlin theorem to allow for the presence of intermediate goods. A modern duality approach is adopted to model a theoretical structure and Helpman's version with free trade will then be reviewed in this framework. Once intermediate goods are in place, we can raise an important issue of whether the calculation of factor contents should be based on only direct factor requirements or gross (direct plus indirect) factor requirements. We show that the result of this analysis depends on whether intermediate goods are traded or nontraded and on where intermediate goods are produced.

Two key issues of the theoretical part of this study are addressed in chapter III. First, we further extend the model to include the case in which all goods, including intermediate goods, are exchanged subject to trade barriers and examine the effects of these impediments on the factor content pattern of trade. Second, we demonstrate that neither direct nor gross factor content calculations provide an appropriate measure for the general case. Instead we develop "home-gross" factor requirements as a valid measure of factor content of trade.

The empirical part of this study is devoted to testing the proposition derived rigorously from the theoretical model, which allows an examination of the Heckscher-Ohlin-Vanek theorem's empirical validity in economies with unequal factor prices. In chapter IV we generalize and implement the model so as to bridge between the theoretical work and the empirical work. In chapter V we describe our data and methods and then report the empirical results.

The concluding chapter summarizes the findings of this study and discuss their limitations and possible extensions for future research.

CHAPTER II

MODEL WITH INTERMEDIATE GOODS

II.1 Introduction

In a recent article, Helpman (1984a) develops a relationship between bilateral factor price differences and the factor content of bilateral trade so as to provide readily testable proposition of the Heckscher-Ohlin theory. The only assumptions required for his results are (1), (3), and (4) in the basic Heckscher-Ohlin-Vanek assumptions described in Chapter I. He shows that his proposition in the factor content of bilateral trade patterns can be tested directly by post-trade data.

As intermediate goods are not explicitly considered in his model, however, one potential problem with this test is how to empirically measure the factor contents embodied in traded goods. One of the aims of this chapter is to extend Helpman's factor content test of the Heckscher-Ohlin theory to a world in which intermediate goods are shown explicitly.

Once intermediate goods are in place we can address an important issue that arises in any empirical exploration of factor proportions international trade theory. The question arises when we consider whether the calculations of factor contents and intensities should be based on only "direct"

inputs or on "direct plus indirect" (that is, gross) input-output coefficients.¹⁸ As claimed by Hamilton and Svensson (1983), authors investigating the empirical relevance of the theory usually are at a loss as to what should really be employed.

While some theoretical results in favor of the use of gross measurement can be found in Deardorff (1982, 1984), and Hamilton and Svensson (1983), other theoretical support for direct measurement can be found in Staiger (1986).¹⁹ Note that the result of Staiger and those of others are for different test formats. From the relationship among autarky factor prices, factor intensities, and trade (Deardorff), and the relationship among national factor endowments, factor intensities, and trade (Hamilton and Svensson), respectively, the authors derive the conclusion that gross factor intensities are the appropriate determinants of trade since they determine commodity prices in autarky, and thus the pattern of commodity trade. In contrast to their results, Staiger (1986) shows that from the bilateral relationship involving post-trade factor prices, direct factor content calculations are an appropriate measure for this kind of empirical test.

As the two versions of the issue indicate, we must

¹⁸ Since intermediate goods are not considered in the Helpman model, it does not allow the examination of this issue.

¹⁹ Leamer (1980) also demonstrates that work on factor abundance should be based on calculations of total factor requirements, including both direct and indirect inputs.

decide which condition is the valid measure of factor content for our empirical test. To answer this question is the other aim of this chapter. In this chapter we will demonstrate that the answer depends on the role of trade in intermediate goods. If intermediate goods are nontraded, the appropriate calculations of factor content are based on gross factor requirements. On the other hand, if such goods are freely traded, direct requirements provide a valid measurement of factor content. At the same time, depending on where the intermediate goods are produced, the gross requirements also provide an appropriate measure of factor content.

Section 2 of this chapter discusses the theoretical structure of the model without intermediate goods. Section 3 extends the model to a world with nontraded intermediate goods. In Section 4 the model is analyzed in a world in which all goods, including intermediate goods, are freely traded. Concluding remarks are given in the final section.

II.2 A Model without Intermediate Goods

Suppose that there are I goods produced with quasi-concave, constant returns to scale technology and M primary factors. Then for each good i we have a production function.

$$(2.1) \quad x_i = f^i(v_i) , \quad i \in I$$

where x_i is output, f^i is concave and homogeneous of

degree one, and $v_i = (v_{i1}, \dots, v_{ni})$ is a vector of inputs of the factors. Define the vector of inputs per unit of output $h_i = v_i / x_i$, so that $f^i(h_i) = 1$. Then for the profit maximizing firm, the cost minimization problem defines the unit (output) cost function for each good i as ²⁰

$$(2.2) \quad c_i(w) = \min_{h_i} \left\{ wh_i \mid f^i(h_i) = 1 \right\}, \quad i \in I$$

where w is the factor price vector. The right hand side of equation (2.2) defines the problem of choosing the vector of inputs per unit of output i , h_i , to minimize the set of input costs, wh_i . The left hand side of the equation, $c_i(w)$, denotes the solution to this problem and is therefore the minimum cost of producing one unit of output i when the input price vector is w .

This unit cost function has the usual properties: it is (1) homogeneous of degree one in the factor price vector w , (2) concave in w ; and (3) non-decreasing in w . Another important property is that the optimum choice of input coefficients for a cost minimizing firm, $h_i(w)$, can be simply obtained by Shepard's lemma as the partial derivatives of the unit cost function with respect to the factor prices.

²⁰ The duality theorem implies that the cost function retains all the information contained in the production function, so there is no loss of information in using the cost function. See, for modern duality theory, Dixit and Norman (1980), Woodland (1982), or Varian (1984), and, for empirical applications to international trade theory, many authors in Feenstra (1988).

$$(2.3) \quad h_{mi}(w) = \frac{\partial c_i(w)}{\partial w_m}, \quad m \in M, \quad i \in I$$

where $h_{mi}(w)$ is an element of $h_i(w)$, representing the demand for factor m per unit of output of good i . With constant returns to scale, the best choice of v_i to produce output x_i when factor prices are w is simply $x_i h_i(w)$.

Now consider the set of commodities, I^{ab} , which are produced in country b and imported by country a . If we let T^{ab} denote the vector of total commodity imports by country a from country b such that $T^{ab} = [t_1^{ab}, \dots, t_I^{ab}]$, we then define the vector of gross factors embodied in total imports as

$$(2.4) \quad T_V^{ab} = \sum_i h_i(w^b) t_i^{ab}, \quad i \in I^{ab}$$

where $h_i(w^b) = [h_{1i}(w^b), \dots, h_{mi}(w^b)]$ is a vector of cost minimizing unit factor requirements used in the production of good i for w^b , which is a vector of post-trade equilibrium factor prices in country b . This calculates the actual factor content of trade using the input-output coefficients of the exporter (here country b).

We multiply both sides of the equation by w^b to obtain

$$(2.5) \quad w^b T_V^{ab} = w^b \sum_i h_i(w^b) t_i^{ab}, \quad i \in I^{ab}$$

Since $c_i(w) = w_i^b \sum_i h_i(w^b)$ according to equation (2.2), defining a vector function c with component functions c_i ,

we rewrite equation (2.5) as follows

$$(2.6) \quad w_{T_v}^{b,ab} = c(w^b) T^{ab}$$

We also know that any good produced in competitive equilibrium will have unit (= marginal) cost equal to price, implying

$$(2.7) \quad w_{T_v}^{b,ab} = p T^{ab}$$

where p is the vector of the free trade prices of the set of commodities.

Next consider the post-trade equilibrium factor price vector in country a , w^a , satisfying

$$(2.8) \quad p_i \leq c_i(w^a) \quad , \quad i \in I$$

Since $c_i(w^a)$ is minimum unit cost over the feasible input coefficients, $h_i(w^a)$, when factor price vector is w^a , we must have

$$(2.9) \quad w^a \sum_i h_i(w^a) \leq w^a \sum_i h_i(w^b) \quad , \quad i \in I$$

Using equations (2.4), (2.8) and (2.9), we obtain

$$\begin{aligned} (2.10a) \quad p T^{ab} &= \sum_i p_i t_i^{ab} \leq \sum_i c_i(w^a) t_i^{ab} \\ &= w^a \sum_i h_i(w^a) t_i^{ab} \\ &\leq w^a \sum_i h_i(w^b) t_i^{ab} \quad , \quad \text{for all } i \in I^{ab} \end{aligned}$$

or

$$(2.10b) \quad pT^{ab} \leq w^a T_V^{ab}$$

By combining equation (2.7) and equation (2.10b) we have

$$(2.11) \quad w^b T_V^{ab} \leq w^a T_V^{ab}$$

or

$$(2.12) \quad (w^a - w^b) T_V^{ab} \geq 0$$

Condition (2.12) is the Helpman (1984a) test which implies that imports by country a from country b contain on average large factor services which are cheaper in country b than in country a.

It also has been shown that differences in factor endowments are negatively correlated with differences in factor prices.²¹ When combined with this proposition, condition (2.12) also implies that the factor content of imports by country a from country b has on average a greater ratio of factors of production with which country b is well endowed relative to country a than the corresponding ratio in the factor content of exports of country a to country b.²²

II.3 Nontraded Intermediate Goods

²¹ See, for autarky factor price, Dixit and Norman (1980, ch.4) and, for free trade equilibrium factor price, Helpman (1984a).

²² For a two factor case, this result is discussed by Brecher and Choudhri (1982a).

The model so far has assumed that all goods are final goods. In the real world, however, a large proportion of international trade consists of the exchange of intermediate inputs or middle products.²³ In this section we extend the model to a world in which there exist nontraded intermediate goods.²⁴ For simplicity we assume, like Staiger (1986), that intermediate goods are produced with primary inputs only.²⁵

We start with the corresponding production function for good i which now can be written as

$$(2.13) \quad x_i = f^i(v_i^d + v_i^g) \quad i \in \text{final goods}$$

$$(2.14) \quad x_i = f^i(v_i^d) \quad i \in \text{intermediate goods}$$

where v_i^d and v_i^g are the vectors of primary inputs and of intermediate inputs, respectively.

Letting d_i and g_i denote the vectors of those inputs per unit of output respectively, so that $f^i(v_i^d/x_i + v_i^g/x_i) = f^i(d_i + g_i) = 1$, the minimum unit cost function for good i is now defined as

$$(2.15) \quad c_i(w, p) = \min_{d_i, g_i} \{wd_i + pg_i \mid f^i(d_i + g_i) = 1\}, \quad i \in I$$

²³ For the theory of trade in middle products, see Ethier (1982), Sanyal and Jones (1982), and Woodland (1982, ch. 5).

²⁴ By "intermediate good" we mean a good which is produced by some other industry and used as an input for a final good.

²⁵ This assumption is made for simplicity and without any loss of generality. The assumption is relaxed in Chapter IV.

Since $c_i(w) = wd_i$ for intermediate goods according to equation (2.14), it follows that $pg_i = wdg_i$ where d is the matrix of primary input coefficients. Therefore we can rewrite equation (2.15) as

$$(2.16) \quad c_i(w) = \min_{d_i, e_i} \left\{ wd_i + we_i \mid f^i(d_i + e_i) = 1 \right\}, \quad i \in I$$

where $e_i = dg_i$ is the vector of indirect input of factors in the intermediate goods per unit of final good. The unit cost function, as before, is a positive, linearly homogeneous, concave function of w . Since all intermediate goods are produced at home, c is a function of home factor prices only. Then the optimum choices of input coefficients are given by Shepard's lemma as follows: $d_i(w)$ is the optimal primary input of factors per unit output of final good i and $e_i(w)$ is the optimal indirect input of factors in the intermediate goods per unit output of final good i .

Let I^{ab} represent a subset of final goods that are produced in country b and are imported by country a . We denote this amount of imports by t_i^{ab} , $i \in I^{ab}$, or T^{ab} in vector formation. Furthermore we assume that all intermediate inputs needed for final goods are produced in both countries in the post-trade equilibrium, but unlike final goods, they are not traded. In this case each country must use its own intermediate goods to produce final goods. The vector of gross (direct plus indirect) factors embodied in the imports by country a from country b is now defined as

$$(2.17) \quad T_v^{ab} = \left[\sum_i d_i(w^b) + \sum_i e_i(w^b) \right] t_i^{ab}, \quad i \in I^{ab}$$

This calculates the actual factor content of trade using the input-output coefficients of the country b .

In trading equilibrium zero profit conditions hold for all perfectly competitive industries implying unit cost pricing. The competitive factor price vector w , therefore, will have the property that

$$(2.18) \quad pT^{ab} = w^b T_d^{ab} + w^b T_e^{ab}$$

where T_d^{ab} and T_e^{ab} represent the vectors of primary factor content and of indirect factor content respectively in total imports by country a from country b such that

$$(2.19) \quad T_d^{ab} = \sum_i d_i(w^b) t_i^{ab}, \quad i \in I^{ab}$$

and

$$T_e^{ab} = \sum_i e_i(w^b) t_i^{ab}, \quad i \in I^{ab}$$

From the new definition of the cost function (2.16) and the analogous reason discussed in equation (2.8) and equation (2.9) it also will have the following property:

$$\begin{aligned} (2.20) \quad pT^{ab} &= \sum_i p_i t_i^{ab} \\ &\leq \sum_i c_i(w^a) t_i^{ab} \\ &= \left[w^a \sum_i d_i(w^a) + w^a \sum_i e_i(w^a) \right] t_i^{ab} \end{aligned}$$

$$\leq \left[w^a \sum_i d_i(w^b) + w^a \sum_i e_i(w^b) \right] t_i^{ab},$$

for all $i \in I^{ab}$

or by equation (2.19)

$$(2.21) \quad pT^{ab} \leq w_{T_d}^{aT^{ab}} + w_{T_e}^{aT^{ab}}$$

By combining equation (2.18) and equation (2.21) we have the condition which the factor content pattern of bilateral trade must satisfy under the assumption of nontraded intermediate goods:

$$(2.22) \quad w_{T_d}^{bT^{ab}} + w_{T_e}^{bT^{ab}} \leq w_{T_d}^{aT^{ab}} + w_{T_e}^{aT^{ab}}$$

or

$$(2.23) \quad (w^a - w^b) (T_d^{ab} + T_e^{ab}) \geq 0$$

It follows that the trade pattern is determined by post-trade bilateral factor price differences, taking into account also the use of factors in the production of nontraded goods used to produce final traded goods. Since $T_v^{ab} = T_d^{ab} + T_e^{ab}$ due to the definitions of equation (2.17) and equation (2.19), condition (2.23) reduces to condition (2.12) for the final good model in the previous section. Thus if intermediate goods are not traded between countries, then it is easy to show that Helpman's test (1984a) extends to the use of gross (direct plus indirect) requirements.

In the two factor case Helpman's test can be better

understood by means of a Lerner diagram as in Figure 2.1. The unit isocost line corresponding to one dollar's worth of factor inputs for country j is represented by the downward sloping line with slope (w_L^j / w_K^j) , $j = a$ and b ; aa for country a and bb for country b . Its unit-value isoquant of good i , $i = 1, 2$, describes the combination of factor inputs that produce the output level $1/p_i$. Any commodity produced by country j must have a unit-value isoquant tangent to its unit isocost line.²⁶ Suppose commodity 1 is produced by country b at point B and exported to country a . Its factor input coefficients are denoted by h_{L1}^b and h_{K1}^b which represent gross (direct plus indirect) requirements of labour and capital, respectively, for producing one dollar's worth of commodity 1.

We can derive the following relationship (2.24) directly from Figure 2.1.

$$(2.24) \quad w_L^a h_{L1}^b + w_K^a h_{K1}^b \geq w_L^b h_{L1}^b + w_K^b h_{K1}^b = \$ 1$$

where w_L^j and w_K^j denote the nominal values of labour's wage rate and capital's rental rate, respectively, in country j , while h_{L1}^b and h_{K1}^b denote the quantities of labour and capital, respectively, used by country b to produce one dollar's worth of commodity 1 imported by country a . This

²⁶ The standard HO assumptions imply that if a unit value isoquant were to lie outside the line $aa(bb)$, the commodity would not be produced in country a (country b), while if it lay inside the line $aa(bb)$, its production would yield a positive profit.

Figure 2.1
Unit-Value Isoquants

implies that unit cost of production would be higher if foreign (here country a) instead of home (here country b) factor requirements were used to produce a good (here commodity 1) at home prices. It is clear from the figure that the dotted isocost line (a-a-) that passes through point B (h_{K1}^b, h_{L1}^b) is farther from the origin than the solid unit isocost line (aa).

Equation (2.24) leads to a two factor version of condition (2.23) such that

$$(2.25) \quad (w_L^a - w_L^b) h_{L1}^b + (w_K^a - w_K^b) h_{K1}^b \geq 0$$

Since the factor coefficients consist of direct and indirect requirements of primary factors, the calculation of factor contents is consistent with gross factor requirements.

II.4 Freely Traded Intermediate Goods

In a recent article Staiger (1986) extends Helpman's (1984a) analysis to a world in which intermediate goods are freely traded, and shows that Helpman's test holds only in terms of direct requirements. Staiger's result requires only one assumption in addition to those employed by Helpman. Intermediate goods are produced with primary inputs only and freely traded between countries. In this section we demonstrate, with the same assumptions as in Staiger (1986), the following results: If the intermediate goods are produced in only country a but the final goods

are produced in country b , then direct requirements provide a valid measure of factor content; whereas if both the intermediate goods and the final goods are produced in country b , then both direct and gross factor requirements can provide a relevant measure of factor content.

We consider the following two special cases.

Special Case 1. The intermediate goods are produced in country a only.

In free trading equilibrium, intermediate goods are assumed to be produced most cheaply in country a , but the final goods are produced in country b and exported to country a . For the competitive factor price vectors, w^a and w^b , a zero profit equilibrium condition implies

$$(2.26) \quad pT^{ab} = w^b T_d^{ab} + w^a T_e^{ab}$$

where $T_e^{ab} = \sum_i e_i^*(w^a) t_i^{ab}$, $i \in I^{ab}$ and $e_i^*(w^a)$ represents the indirect factor embodied in country a 's intermediate inputs imported by country b . The reason is that the industries in country b will produce the final goods by importing intermediate goods from country a , which are available to all countries at the same price. It also implies

$$\begin{aligned} (2.27) \quad pT^{ab} &= \sum_i c_i (w^a) t_i^{ab} \\ &= \left[w^a \sum_i d_i (w^a) + w^a \sum_i e_i (w^a) \right] t_i^{ab} \end{aligned}$$

$$\leq \left[w^a \sum_i d_i (w^b) + w^a \sum_i e_i^* (w^a) \right] t_i^{ab},$$

for all $i \in I^{ab}$

or

$$(2.28) \quad pT^{ab} \leq w^a T_d^{ab} + w^a T_e^{ab}$$

Substituting equation (2.26) into equation (2.28) and rearranging yields

$$(2.29) \quad (w^a - w^b) T_d^{ab} \geq 0$$

This condition is the same as the corresponding condition derived by Staiger (1986), and thus Staiger's proposition, which advocates direct requirements for evaluating the empirical implications of the Heckscher-Ohlin model, is confirmed in this case.

To show that gross requirements are an invalid measure Staiger (1986) also provides a numerical example. It shows that if we employ a gross in place of a direct factor content measurements for T_d^{ab} , then the inequality sign of condition (2.29) is reversed, implying incorrect rejection of the hypothesis.²⁷ However, we can not say that gross calculation is an inappropriate measurement under the free trade assumption.

The intuition behind this stand is reflected in Figure 2.2 where the free trade situation is depicted as the

²⁷ We provide a counter example to Staiger's proposition under the general case in Chapter III.

Figure 2.2
Unit-Value-Added Isoquants

unit-value-added isoquants and unit-isocost lines in the two country and two factor case. The argument of Figure 2.1 in the previous section remains intact if unit-value isoquants are replaced by unit-value-added isoquants.

In this figure the lines aa and bb are unit isocost lines, as before, representing the combination of factors which would cost one dollar in country a and in country b , respectively. The isoquants f_a and i_a , unlike in Figure 2.1, are unit-value-added isoquants that represent the combination of primary factor inputs producing one dollar's worth of value added of the final good; (h_{kf}, h_{lf}) and the intermediate good; (h_{ki}, h_{li}) , respectively. Given factor prices, the slopes of the unit isocost lines are determined. The condition for cost minimization implies that the unit isocost line be tangent to the unit-value-added isoquant. Under this condition country a produces the intermediate good at point A and exports it to country b , while country b produces a final good at point B by importing the intermediate good from country a .

Because the dotted isocost line ($a-a'$) that passes through point B lies clearly outside the unit isocost line (aa), it is evident that the cost of value-added would be higher if country b 's in place of country a 's factor requirements were used to produce the final good at country a 's factor prices. Furthermore it must be true also, by comparing the line bb with the line $b-b'$, that the cost of production of the intermediate good would be higher if it

was produced in country *b* than in country *a*. Since the isoquant f_d now stands for the combination of primary factor input producing one dollar's worth of value added of final good, direct requirements are relevant for the explanation of the factor content of trade.

Another way of viewing in this example is to look at gross factor requirements in this situation. Since the coefficients (h_{ki} , h_{li} , a_{kf} , h_{lf}) in Figure 2.2 now denote only primary factor requirements for producing one dollar's worth of value added, country *b*'s combination of factors used both directly and indirectly to produce this country's one dollar's worth of value added exports of final good must lie on the right of *BE* as well as above *EA*. If the gross (direct plus indirect) factor requirements lie somewhere in the shaded area, say point *C* where it lies below the line *bb*, implying the final good will be produced in country *b* but above the line *aa*, implying the final good will be not produced in country *a*, then gross factor requirements also provide a valid measure of factor content. However, if it lies some elsewhere other than the shaded area but within the boundary *BEA*, say point *D*, then gross factor content calculations are not a relevant measure.

We now turn to the other case which provides a formal verification of this possibility using the framework laid out here.

Special Case 2. *The intermediate goods are produced in country *b* only.*

The intermediate goods are assumed to be produced most cheaply in country b in the post-trade equilibrium, but the same final goods are produced in country b and exported to country a . In this case we have

$$(2.30) \quad pT^{ab} = w^b T_d^{ab} + w^b T_e^{ab}$$

and

$$\begin{aligned} (2.31) \quad pT^{ab} &\leq \sum_i c_i (w^a) t_i^{ab} \\ &= \left[w^a \sum_i d_i (w^a) + w^b \sum_i e_i^* (w^b) \right] t_i^{ab} \\ &\leq \left[w^a \sum_i d_i (w^b) + w^b \sum_i e_i (w^b) \right] t_i^{ab}, \\ &\quad \text{for all } i \in I^{ab} \end{aligned}$$

or

$$(2.32) \quad pT^{ab} \leq w^a T_d^{ab} + w^b T_e^{ab}$$

The second term in the square bracket at the right hand side of equation (2.31) implies that if country a produced the final goods, then country a might import the intermediate inputs required to produce the final goods from country b . From equation (2.30) and equation (2.32) we have

$$(2.33) \quad (w^a - w^b) T_d^{ab} \geq 0$$

Staiger's proposition is established again in this special case.

However, we show that Helpman's test also holds in terms of gross requirements in this case. By handling

equation (2.31) somewhat differently we can demonstrate this result. Since intermediate goods are produced most cheaply in country b , we have

$$(2.34) \quad \left[w^b \sum_i e_i^*(w^b) \right] t_i^{ab} \leq \left[w^a \sum_i e_i(w^a) \right] t_i^{ab}$$

That is, the cost of foreign (here country b) intermediate goods would be higher if they were produced at home (here country a). Replacing the second term in the square bracket on the right hand side of equation (2.31) by the term in the square bracket on the right hand side of eq (2.34) we have

$$\begin{aligned} (2.35) \quad pT^{ab} &\leq \sum_i c_i(w^a) t_i^{ab} \\ &\leq \left[w^a \sum_i d_i(w^a) + w^a \sum_i e_i(w^a) \right] t_i^{ab} \\ &\leq \left[w^a \sum_i d_i(w^b) + w^a \sum_i e_i(w^b) \right] t_i^{ab}, \\ &\quad \text{for all } i \in I^{ab} \end{aligned}$$

or

$$(2.36) \quad pT^{ab} \leq w^a T_d^{ab} + w^a T_e^{ab}$$

From equation (2.30) and equation (2.36) we now have another constraint on the factor content of bilateral trade in free trade.

$$(2.37) \quad (w^a - w^b) (T_d^{ab} + T_e^{ab}) \geq 0$$

This constraint tells us that direct plus indirect calculations are relevant for evaluating the empirical implications of the Heckscher-Ohlin model.

II.5 Concluding Remarks

We have extended Helpman's factor content version to a world in which international trade takes place in intermediate goods as well as final goods, thereby allowing for the examination of the appropriate measurement of factor content.

At one level the result seems to depend on the question of whether intermediate goods are traded or nontraded. If they are not traded between countries, then Helpman's test extends to using gross requirements, taking into account also the use of factors in the production of nontraded goods used to produce final traded good. On the other hand, if they are freely traded between countries, Staiger's proposition, which advocates using direct rather than gross calculation in determining the factor content of trade, is confirmed. At the same time, depending on where the intermediate goods are produced, the factor content of trade might be appropriately measured on the basis of gross factor requirements.

The issue so far has been analyzed in some special cases. The same result, however, could be obtained for the general case in which the intermediate goods were produced in both countries in the post-trade equilibrium. In the

next chapter we examine the arguments in the general case but in the presence of protection afforded by trade barriers.

CHAPTER III

MODEL WITH TRADE BARRIERS

III.1 Introduction

The most common form of government interventions in international trade is the imposition of import duties or tariffs on intermediate goods as well as final goods. Also, in most cases, all goods are transported internationally at a cost. Up to this point, however, the analysis of the factor content pattern of trade has been based on the assumption of free trade. It is the aim of this chapter to extend further the model developed in the previous chapter to a world with transport costs and/or other protective instruments such as import tariffs ("trade barriers"), thereby allowing prices of traded goods to differ across countries. We then analyze the effects of these impediments on the factor content pattern of trade and on the appropriate measure of factor content. We find that tests based on direct measurement of factor content run into trouble in a world of trade barriers, a possibility that Staiger (1986) acknowledges but does not demonstrate it. We thus develop a revised test based on a new measurement.

The rest of this chapter is organized as follows. Section 2 extends the model to allow for trade barriers and

shows that both direct and "home-gross" requirements tests are relevant for evaluating the empirical implications of the Heckscher-Ohlin model. Section 3 further extends the model to allow for both trade barriers and nontraded goods. In this case we find that direct or gross requirements are not workable, whereas "home-gross" requirements are still valid. Finally, Section 4 offers concluding remarks.

III.2 Impeded Trade

In this section we introduce trade barriers and assume that intermediate goods are produced in both countries and that both domestic and foreign produced intermediate goods are required to produce final goods. We also assume that trade in goods, including intermediate goods, is subject to trade barriers (possibly zero in some cases), so that post-trade equilibrium prices in country a and in country b are not the same. At present, we assume that all goods are traded so that domestic and foreign prices differ by exactly the amount of tariffs.

Trade barriers may consist of tariffs, nontariff barriers which have tariff equivalents, or transport costs. Let the cost of trade barriers or, simply "tariffs" on export good i from country $b(a)$ to country $a(b)$ [expressed as a portion of price in country $b(a)$] be $s_i^a(s_i^b)$.²⁸ This implies

²⁸ In a perfectly competitive market it does not matter

$$(3.1) \quad p_i^a = p_i^b (1+s_i^a) \quad , \quad s_i^a \geq 0 \quad , \quad i \in I$$

or

$$p_i^b = p_i^a (1+s_i^b) \quad , \quad s_i^b \geq 0 \quad , \quad i \in I$$

The minimum unit cost function in this case needs to be redefined as

$$(3.2) \quad c_i(w, p, p^*) = \min_{d_i, g_i, g_i^*} \left\{ wd_i + pg_i + p^*g_i^* \mid f^i(d_i + g_i + g_i^*) = 1 \right\} \quad , \quad i \in I$$

where the asterisk denotes the foreign country. Since $c_i(w^*) = w^*d_i^*$ for intermediate goods according to equation (2.14), it follows that $p^*g_i^* = w^*d_i^*g_i^*$. Therefore we can rewrite equation (3.2) as

$$(3.3) \quad c_i(w, w^*) = \min_{d_i, e_i, e_i^*} \left\{ wd_i + we_i + w^*e_i^* \mid f^i(d_i + e_i + e_i^*) = 1 \right\} \quad , \quad i \in I$$

where $e_i^* = d_i^*g_i^*$ is the vector of indirect factor embodied in foreign produced intermediate inputs per unit output of final good i . Now c is a function of foreign factor prices as well as of domestic factor prices. We use this cost function to show that both the modified direct and

whether the tariff is a specific tariff per physical unit or an ad valorem tariff levied as a fraction of the value of the imported goods. We simply choose an ad valorem tariff at a rate s .

"home-gross" requirements can be supported by a model with trade barriers. First, we derive factor requirements in terms of direct requirements. Let

$$(3.4) \quad T_d^{ab} = \sum_i d_i^b(w^a, w^b) t_i^{ab}, \quad i \in I^{ab}$$

$$(3.5) \quad T_{eb}^{ab} = \sum_i e_i^b(w^a, w^b) t_i^{ab}, \quad i \in I^{ab}$$

$$(3.6) \quad T_{ea}^{ab} = \sum_i e_i^{a*}(w^a, w^b) t_i^{ab}, \quad i \in I^{ab}$$

where T_{ea}^{ab} (T_{eb}^{ab}) represents the vector of indirect factors embodied in the intermediate goods produced in country a (in country b) which are required to produce the final total imports by country a from country b. Then define the vector of gross (direct plus indirect) factors embodied in the total imports as

$$(3.7) \quad T_v^{ab} = \left[\sum_i d_i^b(w^a, w^b) + \sum_i e_i^b(w^a, w^b) + \sum_i e_i^{a*}(w^a, w^b) \right] t_i^{ab}, \quad i \in I^{ab}$$

Under these conditions country b will produce final goods by purchasing some intermediate inputs from its home market and by importing others from abroad (here country a), thereby paying a tariff of a rate s_j , $j \in I$, per unit of the intermediate good j. If we let g_{ji} represent the amount of import of intermediate good j used in the production of one unit of final good i, the tariff at a

rate s_j on the intermediate goods will generate tax revenue per unit of final good i by $\sum_j g_{ji} p_j^a s_j^b$, $j \in I$, according to equation (3.1). In such a case a zero profit equilibrium condition implies

$$(3.8) \quad p^{bT^{ab}} = w^{bT_d^{ab}} + w^{bT_{eb}^{ab}} + w^{aT_{ea}^{ab}} + Q^b$$

where $Q^b = \sum_i \sum_j t_i^{ab} g_{ji} p_j^a s_j^b$ stands for the sum of tariffs paid for the intermediate imports from country a , from the industry's point of view, or for revenue, from the government's point of view.

Next consider the post-trade equilibrium factor price vectors in country a and in country b , w^a and w^b , satisfying

$$(3.9) \quad p_i \leq c_i^a(w^a, w^b), \quad i \in I$$

Since $c_i^a(w^a, w^b)$ is minimum unit cost over the feasible input coefficients: $d_i^a(w^a, w^b)$, $e_i^a(w^a, w^b)$, and $e_i^{b*}(w^a, w^b)$, when the vectors of factor prices are w^a and w^b , we have

$$\begin{aligned} (3.10) \quad p^{aT^{ab}} &\leq \sum_i c_i^a(w^a, w^b) t_i^{ab} \\ &= \left[w^a \sum_i d_i^a(w^a, w^b) + w^a \sum_i e_i^a(w^a, w^b) \right. \\ &\quad \left. + w^b \sum_i e_i^{b*}(w^a, w^b) + \sum_i \sum_j g_{ji} p_j^b s_j^a \right] t_i^{ab} \end{aligned}$$

$$\begin{aligned}
&= \left[w^a \sum_i d_i^b(w^a, w^b) + w^a \sum_i e_i^{a*}(w^a, w^b) \right. \\
&\quad \left. + w^b \sum_i e_i^b(w^a, w^b) + \sum_i \sum_j g_{ji} p_j^b s_j^a \right] t_i^{ab}.
\end{aligned}$$

for all $i \in I^{ab}$, $j \in I$

which implies that the cost of final goods would be higher if foreign instead home feasible input coefficients were used to produce such goods at home prices. By the relationships of equation (3.4) through equation (3.6) this reduces to

$$(3.11) \quad p^a T^{ab} = w^a T_d^{ab} + w^a T_{ea}^{ab} + w^b T_{eb}^{ab} + Q^a$$

where $Q^a = \sum_i \sum_j t_i^{ab} g_{ji} p_j^b s_j^a$. Rearranging equation

(3.11) and combining equation (3.8) yields

$$\begin{aligned}
(3.12) \quad &w^a T_d^{ab} + w^a T_{ea}^{ab} + w^b T_{eb}^{ab} + Q^a \geq p^a T^{ab} \\
&= p^b T^{ab} + (p^a - p^b) T^{ab} \\
&= w^b T_d^{ab} + w^b T_{eb}^{ab} + w^a T_{ea}^{ab} + Q^b + R^a
\end{aligned}$$

where $R^a = (p^a - p^b) T^{ab}$. According to equation (3.1), R^a can be rewritten as $R^a = \sum_i t_i^{ab} p_i^b s_i^a$ which stands for the total tariff revenue collected by country a on the imports of final goods from country b . Equation (3.12) reduces to

$$(3.13) \quad (w^a - w^b) T_d^{ab} \geq (R^a - Q^a) + Q^b$$

This provides a restriction that relates the post-trade factor price differences to the direct factor content of trade. If the right-hand side of equation (3.13), $(R^a - Q^a + Q^b)$, is equal to zero, Staiger's proposition is confirmed. If it is greater than zero, the test of factor content of trade holds in terms of a modified direct factor requirement.

Note that the first term at the right-hand side of the restriction, $(R^a - Q^a)$, depends on the rate of effective protection. The rate of effective protection, θ , is defined as the percentage increase in value added per unit of output which is made possible by tariff structure, relative to the situation in the absence of tariffs. Thus we have²⁹

$$\theta = \frac{s_i - \sum_j \epsilon_{ji} s_j}{1 - \sum_j \epsilon_{ji}}, \text{ where } \epsilon_{ji} = \frac{G_{ji} p_j}{t_i^{ab} p_i} \text{ and}$$

$$G_{ji} = g_{ji} t_i^{ab}.$$

ϵ_{ji} is the share of intermediate good in the total cost of producing final good i (t_i^{ab}) and G_{ji} is the amount of intermediate good j used to produce the amount of final good i (t_i^{ab}). In our model the gross revenue of import

²⁹ See Appendix A for the full description of the rate of effective protection.

tax on the final good i is $R_i^a = t_i^{ab} p_i^b s_i^a$, while the gross revenue of import tax on the intermediate good j is $Q_i^a = \sum_j g_{ji} p_j^b s_j^a t_i^{ab} = \sum_j G_{ji} p_i^b s_j^a$. Thus

$$\begin{aligned} (3.14) \quad R_i^a - Q_i^a &= t_i^{ab} p_i^b s_i^a - \sum_j G_{ji} p_j^b s_j^a \\ &= \left(s_i^a - \sum_j c_{ji} s_j^a \right) t_i^{ab} p_i^b \end{aligned}$$

The term in the parenthesis is identical to the numerator in the rate of effective protection.

Therefore equation (3.13) implies that factor price differences and the effective rate of protection together determine the factor content of trade. In so doing the rate of effective protection is higher, the greater the importance of bilateral factor-price differences in the post-trade equilibrium. This is an interesting result. Thus the issue may be linked to the effective rate of protection in this case. The rate of effective protection can be negative if the tariff on intermediate inputs is sufficiently higher than the tariff on final goods, or if there is no tariff on final goods. If it were true, then $(R^a - Q^a)$ could be on average negative and the negative magnitude large enough to dominate the positive magnitude of Q^b such that $|R^a - Q^a| > Q^b$. As a result, this case would lead to violation of a modified direct requirements test that $(w^a - w^b) T_d^{ab}$ exceeds some positive value. Consequently, the modified direct requirement test holds sufficiently if the rate of effective protection is on

average positive.

Now we derive factor requirements in terms of "home-gross" requirements. The home-gross requirements test holds whether all trade barriers are zero or positive in some degree. We can show that by handling equation (3.10) somewhat differently. Consider the following condition

$$(3.15) \quad \left[w^b \sum_i e_i^{b*}(w^a, w^b) + \sum_i \sum_j g_{ji} p_j^b s_j^a \right] t_i^{ab} \\ \leq \left[w^a \sum_i e_i^{ba}(w^a, w^b) \right] t_i^{ab}$$

where $e_i^{ba}(\cdot)$ represents the indirect requirements in the production of country b 's intermediate goods if these goods were to be produced in country a . It implies that the cost of foreign (here country b) intermediate goods would be higher if they were produced at home (here country a). Accordingly, replacing the third term in the square bracket at the right hand side of equation (3.10) by the term in the square bracket at the right hand side of equation (3.15) we have

$$(3.16) \quad p^a T^{ab} \leq \sum_i c_i^a(w^a, w^b) t_i^{ab} \\ \leq \left[w^a \sum_i d_i^a(w^a, w^b) + w^a \sum_i e_i^a(w^a, w^b) \right. \\ \left. + w^a \sum_i e_i^{ba}(w^a, w^b) \right] t_i^{ab}$$

$$\leq \left[w^a \sum_i d_i^b (w^a, w^b) + w^a \sum_i e_i^{a*} (w^a, w^b) + w^a \sum_i e_i^b (w^a, w^b) \right] t_i^{ab},$$

for all $i \in I^{ab}$

From equations (3.4) through (3.6), this reduces to

$$(3.17) \quad p^{a,b} \leq w^a T_d^{ab} + w^a T_{ea}^{ab} + w^a T_{eb}^{ab}$$

The relationship between equation (3.8) and equation (3.17) provides another restriction on the factor content of bilateral trade in the presence of trade barriers and intermediate goods.

$$\begin{aligned} (3.18) \quad w^a T_d^{ab} + w^a T_{ea}^{ab} + w^a T_{eb}^{ab} &\geq p^a T^{ab} \\ &= p^b T^{ab} + (p^a - p^b) T^{ab} \\ &= w^b T_d^{ab} + w^b T_{eb}^{ab} + w^a T_{ea}^{ab} + Q^b + R^a \end{aligned}$$

Rearranging we have

$$(3.19) \quad (w^a - w^b) (T_d^{ab} + T_{eb}^{ab}) \geq R^a + Q^b \geq 0$$

This is a restriction that relates post-trade bilateral factor price differences to "home-gross" requirements, consisting of both the direct factor inputs into final goods and only the direct factor inputs into the home (here country b) produced intermediate goods required to produce the final goods.

We can also show that the home-gross requirements test holds under the special case in which the intermediate goods are produced in only one country in the post-trade equilibrium. In general home-gross requirements are different from both direct and gross requirements. In the special case, however, there is no difference between them. If the intermediate goods are produced in only country *a* but the final goods are produced in country *b*, then home-gross requirements are the same as direct requirements by definition. On the other hand, if both the intermediate goods and the final goods are produced in country *b* only, then home-gross requirements are the same as gross requirements by definition (for proof see Appendix B).

III.3 Both Trade Barriers and Nontraded Goods

In the last section, we assume that all tariffs exactly equal the differences between domestic and foreign prices and that all goods are traded. Finally, in this section, we allow for the possibility of prohibitive tariffs (or zero quota) for some goods so that such goods are not traded. We extend the model to include both trade barriers and nontraded goods and show that neither direct nor gross factor requirements provide a valid measure of the factor content of trade. We demonstrate instead that only the "home-gross" factor requirements test is relevant for evaluating the empirical implications of the Heckscher-Ohlin model.

We assume that foreign traded intermediate goods as well as both traded and nontraded domestic intermediate goods are required to produce the final goods. In this case the minimum unit cost function for good i (equation 3.3) defined in the previous section is modified as

$$(3.20) \quad c_i(w, w^*) = \min_{d_i, e_i^1, e_i^2, e_i^{1*}} \left\{ w d_i + w e_i^1 + w e_i^2 + w^* e_i^{1*} \right. \\ \left. \mid f^i(d_i + e_i^1 + e_i^2 + e_i^{1*}) = 1 \right\}, \quad i \in I$$

where the asterisk denotes the foreign country and the number 1 and 2 denote traded intermediate goods and nontraded intermediate goods, respectively. The optimum choice of input coefficients $(d_i, e_i^1, e_i^2, e_i^{1*})$ are simply given by Shepard's lemma as the partial derivatives of the minimum unit cost function with respect to the factor prices as before. Then the corresponding vector of gross factor contents in total imports by country a from country b is defined as

$$(3.21) \quad T_v^{ab} = T_d^{ab} + T_{e^1}^{ab} + T_{e^2}^{ab} + T_{e^{1*}}^{ab}$$

where $T_{e^1}^{ab}$ and $T_{e^{1*}}^{ab}$ denote the vectors of indirect factor contents in the traded intermediate goods produced in country b and in country a , respectively, which are required to produce final total imports by country a from country b , while $T_{e^2}^{ab}$ denotes the vector of indirect factor content in country b 's nontraded intermediate goods used up to produce

the final total imports.⁵¹

Industries in country b will produce final goods both by using domestic traded and nontraded intermediate inputs and by importing foreign traded intermediate inputs from country a , thereby paying the tariffs, and export them to country a . In such a case a similar argument discussed in earlier sections shows that

$$(3.22) \quad p^b T^{ab} = w^b T_d^{ab} + w^b T_e^{1b} + w^b T_e^{2b} + w^a T_e^{1a} + Q^b$$

From the new definition of cost function (3.20) and the analogous reason discussed in equation (3.9) and equation (3.10) this function also has the following property⁵²

⁵¹ It is defined as

$$\begin{aligned} T_d^{ab} &= \sum_i d_i^b (w^a, w^b) t_i^{ab}, & i \in I^{ab} \\ T_e^{1b} &= \sum_i e_i^{1b} (w^a, w^b) t_i^{ab}, & i \in I^{ab} \\ T_e^{2b} &= \sum_i e_i^{2b} (w^a, w^b) t_i^{ab}, & i \in I^{ab} \\ T_e^{1a} &= \sum_i e_i^{1a*} (w^a, w^b) t_i^{ab}, & i \in I^{ab} \end{aligned}$$

⁵² Since $\left[w^b \sum_i e_i^{1b*}(\cdot) + \sum_i \sum_j g_{ji} p_j^b s_j^a \right] t_i^{ab} \leq \left[w^a \sum_i e_i^{1ba}(\cdot) \right] t_i^{ab}$ we have

$$\begin{aligned} p^a T^{ab} &\leq c_i^a (w^a, w^b) t_i^{ab} \\ &= \left[w^a \sum_i d_i^a(\cdot) + w^a \sum_i e_i^{1a}(\cdot) + w^a \sum_i e_i^{2a}(\cdot) + w^b \sum_i e_i^{1b*}(\cdot) + \sum_i \sum_j g_{ji} p_j^b s_j^a \right] t_i^{ab} \\ &\leq \left[w^a \sum_i d_i^a(\cdot) + w^a \sum_i e_i^{1a}(\cdot) + w^a \sum_i e_i^{2a}(\cdot) + w^a \sum_i e_i^{1ba}(\cdot) \right] t_i^{ab} \\ &\leq \left[w^a \sum_i d_i^b(\cdot) + w^a \sum_i e_i^{1a*}(\cdot) + w^a \sum_i e_i^{2b}(\cdot) + w^a \sum_i e_i^{1b}(\cdot) \right] t_i^{ab} \end{aligned}$$

reduces to equation (3.23).

$$(3.23) \quad p^a T^{ab} \leq w^a T_d^{ab} + w^a T_e^{ab} 1a + w^a T_e^{ab} 2b + w^a T_e^{ab} 1b$$

The relationship between eq (3.22) and eq (3.23) yields the restriction which the factor content pattern of bilateral trade must satisfy in the presence of nontraded goods as well as trade barriers.³²

$$(3.24) \quad (w^a - w^b) (T_d^{ab} + T_e^{ab} 1b + T_e^{ab} 2b) \geq R^a + Q^b \geq 0$$

Equation (3.24) establishes that only "home-gross" factor requirements are a valid measure of factor content for the general model. Furthermore tests in terms of direct or gross requirements can not be derived such that $(w^a - w^b) T_d^{ab}$ exceeds some positive value. We provide a simple numerical example to highlight this last result. Consider a two country (a and b), two factor (labour and capital), four good (one final good, one home traded intermediate good, one home nontraded intermediate good, and one foreign traded intermediate good) Heckscher-Ohlin world with the condition described in the model here. Suppose that vectors of post-trade equilibrium factor prices in two countries, a and b, are given by

³² Rearranging equation (3.23) and substituting equation (3.22) in it we have

$$\begin{aligned} w^a T_d^{ab} + w^a T_e^{ab} 1a + w^a T_e^{ab} 2b + w^a T_e^{ab} 1b &\geq p^a T^{ab} \\ &= p^b T^{ab} + (p^a - p^b) T^{ab} \\ &= [\text{the right side in equation (3.22)}] + R^a \end{aligned}$$

Thus this reduces to equation (3.24).

$$w^a = \begin{bmatrix} 5 & 9 \end{bmatrix} \quad \text{and} \quad w^b = \begin{bmatrix} 10 & 6 \end{bmatrix}$$

where each first column represents the wage rate while each second column represents the rental rate. This implies that country a is labour-abundant, while country b is capital-abundant.

Furthermore it is assumed that one unit each of the primary factors, labour and capital, one unit each of home made intermediate goods, one traded and one nontraded, and one unit of a foreign traded intermediate good are required to produce one unit of a final good. On the other hand, one unit of home traded intermediate good is produced with two units of labour and eight units of capital, one unit of home nontraded intermediate good one unit of labour and five units of capital, and one unit of foreign traded intermediate good nine units of labour and two units of capital, respectively. Then the direct inputs of labour and capital, for one unit of final good to be produced, will be required as follows

$$T_d^{ab \prime} = \begin{bmatrix} 1 & 1 \end{bmatrix}$$

$$T_{e1b}^{ab \prime} = \begin{bmatrix} 2 & 8 \end{bmatrix}$$

$$T_{e2b}^{ab \prime} = \begin{bmatrix} 1 & 5 \end{bmatrix}$$

$$T_{e1a}^{ab \prime} = \begin{bmatrix} 9 & 2 \end{bmatrix}$$

respectively, where primes denote transposes.

The trading equilibrium zero profit condition for

competitive factor prices implies that ³³

$$\begin{aligned}
 (3.25) \quad p^{bT^{ab}} &= w^{bT_d^{ab}} + w^{bT_e^{ab}1b} + w^{bT_e^{ab}2b} + w^{aT_e^{ab}1a} + Q^b \\
 &= [10 \quad 6] \begin{bmatrix} 1 \\ 1 \end{bmatrix} + [10 \quad 6] \begin{bmatrix} 2 \\ 8 \end{bmatrix} \\
 &\quad + [10 \quad 6] \begin{bmatrix} 1 \\ 5 \end{bmatrix} + [5 \quad 9] \begin{bmatrix} 9 \\ 2 \end{bmatrix} + Q^b \\
 &= 187 + Q^b
 \end{aligned}$$

and

$$\begin{aligned}
 (3.26) \quad p^{aT^{ab}} &= w^{aT_d^{ab}} + w^{aT_e^{ab}1a} + w^{aT_e^{ab}2b} + w^{aT_e^{ab}1b} \\
 &= [5 \quad 9] \begin{bmatrix} 1 \\ 1 \end{bmatrix} + [5 \quad 9] \begin{bmatrix} 9 \\ 2 \end{bmatrix} \\
 &\quad + [5 \quad 9] \begin{bmatrix} 1 \\ 5 \end{bmatrix} + [5 \quad 9] \begin{bmatrix} 2 \\ 8 \end{bmatrix} \\
 &= 209
 \end{aligned}$$

If $Q^b < 22$, then country b has a clear advantage in the production of the final good so that country b will produce the final goods and export to country a .

The factor content of this trade flow can be calculated by employing each of the following different methods of measurement:

³³ For simplicity it is assumed that only one unit of the final good is imported by country a from country b in the post-trade equilibrium.

Case 1. Home-gross requirements: $\left[(w^a - w^b) (T_d^{ab} + T_e^{ab1b} + T_e^{ab2b}) \right]$

$$[5 - 10 \quad 9 - 6] \begin{bmatrix} 1 + 2 + 1 \\ 1 + 8 + 5 \end{bmatrix} = 22 > 0$$

Case 2. Direct requirements: $\left[(w^a - w^b) T_d^{ab} \right]$

$$[5 - 10 \quad 9 - 6] \begin{bmatrix} 1 \\ 1 \end{bmatrix} = -2 < 0$$

Case 3. Gross requirements: $\left[(w^a - w^b) (T_d^{ab} + T_e^{ab1b} + T_e^{ab2b} + T_e^{ab1a}) \right]$

$$[5 - 10 \quad 9 - 6] \begin{bmatrix} 1 + 2 + 1 + 9 \\ 1 + 8 + 5 + 2 \end{bmatrix} = -17 < 0$$

It is clear that the test of factor content of trade holds only in terms of "home-gross" factor requirements in the general case. However, if we use the same data to test a restriction analogous to (3.24) but employ direct or gross factor requirements, then Heckscher-Ohlin theorem may be incorrectly rejected.

III.4 Concluding Remarks

We have derived the restrictions on the factor content of bilateral trade under various conditions. One interesting finding is that the admission of trade barriers into the model results in some positive number in the right hand side of the restrictions, as compared with the zero value in Helpman's factor content version of the

Heckscher-Ohlin theorem.

The other interesting finding is that neither direct nor gross factor requirements are relevant to explaining the factor contents of trade flows in goods for the general case in which the model allows for the existence of both trade barriers and nontraded goods. We then have developed a revised test based on a new measurement which is referred to as "home-gross" factor requirements. We have established that the home-gross requirements always provide a valid measure of factor content of trade. At the same time the home-gross requirements hold in a world with either free trade or trade barriers and with either freely traded or non-traded intermediate goods.

This result thus will offer an important theoretical foundation when we consider what should really be used in empirical tests of implications arising from the Heckscher-Ohlin model. We discuss this further in the following chapter on empirical design.

CHAPTER IV

EMPIRICAL DESIGN

IV. 1 Introduction

Chapter III has formulated the working proposition that serves as a foundation for the empirical analysis of a factor content version of the Heckscher-Ohlin theorem. The purpose of this chapter is to generalize the theoretical model, discuss various details concerning its implementation, and thereby to serve as a bridge between the theory of the previous chapter and the empirical work in the subsequent chapter.

In the theoretical model dealt with in the previous chapter it has been assumed for simplicity that intermediate goods are produced with direct (or primary) inputs only. The following section shows that the model can be easily extended to allow for the possibility that all good might be used as intermediate inputs.

IV. 2 A General Treatment of Intermediate Goods

Consider a model with two countries trading in a multicountry world, m primary factors, and n goods. Denote the set of factors by M and the set of goods by I .

The set I is divided into three subsets such that $I_\alpha \cup I_\beta \cup I_\gamma = I$, where I_α (I_β) indicates goods that are produced in country a (country b) only; and I_γ indicates goods that are produced in both countries in post-trade equilibrium.³⁴ Now assume that each good i is produced according to the following production function:

$$(4.1) \quad y_i^j = f_i (v_i^j, x_i^j), \quad x_i^j = [x_{i\alpha}^j, x_{i\beta}^j, x_{i\gamma}^j]$$

$$i \in I, \quad j = a, b$$

where y_i^j is the gross output of good i produced in country j ; v_i^j is a $1 \times m$ vector of primary factors used directly to produce good i in country j ; and x_i^j is a $1 \times n$ vector of intermediate inputs [produced in country a only ($x_{i\alpha}^j$), in country b only ($x_{i\beta}^j$), and in both countries ($x_{i\gamma}^j$)] used in the production of good i in country j , respectively.³⁵ It allows for the possibility that foreign intermediate goods as well as domestic intermediate goods are required to produce the final products. If some final products are produced only with domestic inputs, for example, the corresponding vector in x_i^j is set equal to zero.

Letting $p^j = [p_\alpha^j, p_\beta^j, p_\gamma^j]$ represent a $n \times 1$

³⁴ For each of these subsets the model allows for the possibility that there exists traded and nontraded goods.

³⁵ There is a distinction between the gross and net output of the production sector since it is possible that some of good i may be used as an input in the production of i .

vector of prices of goods [in I_α (p_α^j) , in I_β (p_β^j) , and in I_γ (p_γ^j)] in country j and w^j denote a $m \times 1$ vector of prices of primary factor services in country j , respectively, the minimum unit cost function of good i is now defined as

$$(4.2) \quad c_i^j(w^j, p^j) = \min_{v_i^j, x_i^j} \left\{ v_i^j w^j + x_i^j p^j \mid \right.$$

$$\left. f^i(v_i^j, x_i^j) = 1 \right\}, \quad i \in I, \quad j = a, b$$

which, as before, is a positive, linearly homogeneous, concave function of (w, p) . Furthermore, the optimum choice of input coefficients is given by the corresponding partial derivatives of the unit cost function. We may denote this relation by $d_i^j(w^j, p^j)$: a $1 \times m$ vector of the optimal input of primary factors and $g_i^j(w^j, p^j) = \left[g_{i\alpha}^j(w^j, p^j), g_{i\beta}^j(w^j, p^j), g_{i\gamma}^j(w^j, p^j) \right]$: a $1 \times n$ vector of the optimal input of goods per unit of gross output of good i in country j , respectively.³⁶

By the assumption of unequal factor prices, w^a is not equal to w^b . We also focus on the case where goods are exchanged subject to trade barriers so that the post-trade equilibrium prices in country a and in country b are

³⁶ If an input is not used in the production of i , then the derivatives of the cost function with respect to its price is identically zero.

different.³⁷ For any good i in set I this implies that

$$(4.3) \quad p_i^a = p_i^b (1 + s_i^a) \quad , \quad s_i^a \geq 0 \quad ,$$

if i good imported in country a

and

$$(4.4) \quad p_i^b = p_i^a (1 + s_i^b) \quad , \quad s_i^b \geq 0 \quad ,$$

if i good imported in country b

where s_i^a (s_i^b) stands for the ad valorem tariff levied by country a (b) on good i imported from country b (a). Then, since good i in set I_α is not produced in country b , it satisfies the following condition

$$(4.5) \quad c_{i\alpha}^b > p_{i\alpha}^b$$

Similarly, since good i in set I_β is not produced in country a , it satisfies the following condition

$$(4.6) \quad c_{i\beta}^a > p_{i\beta}^a$$

Finally, since good i in set I_γ is produced in both countries we have³⁸

³⁷ If trade in good i is not subject to barriers, then $p_i^a = p_i^b$.

³⁸ Good i in set I_γ is assumed to be produced in both countries. However, if, for example, $c_{i\gamma}^a + \epsilon_{i\gamma}^b = c_{i\gamma}^b$ and $c_{i\gamma}^a < c_{i\gamma}^b$ where $\epsilon_{i\gamma}^b = p_{i\gamma}^a s_{i\gamma}^b$, then country b may produce I_γ goods at home or may import them from country a .

$$(4.7) \quad c_{i\gamma}^b = p_{i\gamma}^b$$

and

$$(4.8) \quad c_{i\gamma}^a = p_{i\gamma}^a$$

Since $c_i^j(w^j, p^j)$ is minimum unit cost of good i in country j over the feasible input coefficients: $d_i^j(w^j, p^j)$ and $g_i^j(w^j, p^j)$, when the vectors of prices of goods and primary factors in country j are w^j and p^j , then the cost minimization condition (4.2) clearly implies that

$$(4.9) \quad d_i^a w^a + g_{i\alpha}^a p_\alpha^a + g_{i\beta}^a p_\beta^a + g_{i\gamma}^a p_\gamma^a \\ \leq d_i^b w^a + g_{i\alpha}^b p_\alpha^a + g_{i\beta}^b p_\beta^a + g_{i\gamma}^b p_\gamma^a$$

It follows that unit cost would be higher if country b 's instead of country a 's factor requirements were used to produce good i at country a 's input prices. This is the basic hypothesis in the theoretical model developed in the previous chapters.

Now consider the set of final goods, $I_\delta = (I_\beta, I_\gamma)$, which are produced in country b . Let the number of goods in I_δ be n_δ and that in I_α (resp. I_β and I_γ), be n_α (resp. n_β and n_γ). Country b will produce I_δ goods by purchasing some intermediate goods from its domestic market and by importing the others from abroad (here country a), thereby paying an ad valorem tariff of a rate s_α . In such

a case the zero profit equilibrium condition implies ³⁹

$$(4.10) \quad T_{\delta} p_{\delta}^b = D^b w^b + G_{\beta}^b p_{\beta}^b + G_{\gamma}^b p_{\gamma}^b + G_{\alpha}^b p_{\alpha}^a + Q_{\alpha}$$

where T_{δ} is a $1 \times n_{\delta}$ vector with $t_{i\delta}$ as its i th column, representing the amount of import of good i in set I_{δ} by country a from country b ⁴⁰; p_{δ}^b is a $n_{\delta} \times 1$ vector of prices of the I_{δ} goods in country b ; D^b is a $1 \times m$ vector with D_m^b as its m th column, representing amounts of primary factor m used directly to produce the gross output of the I_{δ} goods in country b ; G_{β}^b (G_{γ}^b) is a $1 \times n_{\beta}$ ($1 \times n_{\gamma}$) vector with its i th column equal to $G_{i\beta}^b$ ($G_{i\gamma}^b$), giving the requirements of domestic intermediate good i in set I_{β} (domestic intermediate good i in set I_{γ}); G_{α}^b is a $1 \times n_{\alpha}$ vector with its i th column equal to $G_{i\alpha}^b$, giving the requirements of foreign intermediate good i in set I_{α} used up in the production of the gross output of the I_{δ} goods in country b , respectively; and $Q_{\alpha} = \sum_{\alpha} G_{\alpha}^b p_{\alpha}^a s_{\alpha}^b$ stands for the tariff revenue collected by country b on the intermediate imports (G_{α}^b) from country a required directly to produce the I_{δ} goods.

It also will have the following condition which results from both cost minimization condition (4.2) and equation

³⁹ See Appendix C for a full description of equation (4.10).

⁴⁰ If a good in set I_{δ} is not imported by country a from country b , then the relevant element in vector T_{δ} is identically zero.

(4.9).⁴¹

$$(4.11) \quad T_{\delta} p_{\delta}^a \leq D^b w^a + G_{\alpha}^b p_{\alpha}^a + G_{\gamma}^b p_{\gamma}^a + G_{\beta}^b p_{\beta}^a$$

The relationship between equation (4.10) and equation (4.11) provides a restriction on the factor content of bilateral trade in the presence of trade barriers and intermediate goods.⁴²

$$(4.12) \quad D^b (w^a - w^b) + G_{\beta}^b (p_{\beta}^a - p_{\beta}^b) + G_{\gamma}^b (p_{\gamma}^a - p_{\gamma}^b) \geq Q_{\alpha} + R_{\delta}$$

Where $R_{\delta} = T_{\delta} (p_{\delta}^a - p_{\delta}^b)$ stands for the tariff revenue collected by country a on the imports (T_{δ}) from country b .

We restate equation (4.12) in terms of factor prices alone in order to relate it to the tests discussed in Chapters II and III. Since country b produces good i in set I_{δ} , the zero profit condition allow us to infer that average cost is equal to price in country b .

$$(4.13) \quad c_i^b (w^j, p^j) = p_i^b, \quad i \in I_{\delta}, \quad j = a, b$$

⁴¹ See Appendix D for a full description of equation (4.11).

⁴² By rearranging equation (4.11) and combining equation (4.10), we obtain

$$\begin{aligned} D^b w^a + G_{\alpha}^b p_{\alpha}^a + G_{\gamma}^b p_{\gamma}^a + G_{\beta}^b p_{\beta}^a &\geq T_{\delta} p_{\delta}^a \\ &= T_{\delta} p_{\delta}^b + T_{\delta} (p_{\delta}^a - p_{\delta}^b) \\ &= D^b w^b + G_{\beta}^b p_{\beta}^b + G_{\gamma}^b p_{\gamma}^b + G_{\alpha}^b p_{\alpha}^a + Q_{\alpha} + R_{\delta} \end{aligned}$$

where $R_{\delta} = T_{\delta} (p_{\delta}^a - p_{\delta}^b)$. This reduces to equation (4.12).

Equation (4.10) implies that the price of good i can be expressed as

$$(4.14) \quad p_i^b = d_i^b w^b + g_{i\beta}^b p_\beta^b + g_{i\gamma}^b p_\gamma^b + g_{i\alpha}^b p_\alpha^a + q_{i\alpha}, \quad i \in I_\delta$$

where d_i^b is a $1 \times m$ vector; w^b is a $m \times 1$ vector; $g_{i\beta}^b$, $g_{i\gamma}^b$, and $g_{i\alpha}^b$ are $1 \times n_\beta$, $1 \times n_\gamma$, and $1 \times n_\alpha$ vectors, respectively; p_β^b , p_γ^b , and p_α^b are $n_\beta \times 1$, $n_\gamma \times 1$, and $n_\alpha \times 1$ vectors, respectively; and $q_{i\alpha} = \sum_\alpha g_{i\alpha}^b p_\alpha^a s_\alpha^b$ (according to equation 4.4) is a scalar. Since I_δ goods consists of I_β goods plus I_γ goods we can write the vector of prices of all goods in set I_δ as

$$(4.15) \quad p_\delta^b = d^b w^b + g_\delta^b p_\delta^b + g_\alpha^b p_\alpha^a + q_\alpha, \quad I_\delta = I_\beta \cup I_\gamma$$

where p_δ^b is a $n_\delta \times 1$ column vector; d^b is a $n_\delta \times m$ matrix; g_δ^b and g_α^b are, respectively, $n_\delta \times n_\delta$ and $n_\delta \times n_\alpha$ matrices; and q_α is a $n_\delta \times 1$ column vector. Solving equation (4.15) for p_δ^b , we obtain

$$(4.16) \quad p_\delta^b = \Lambda^b d^b w^b + \Lambda^b g_\alpha^b p_\alpha^a + \Lambda^b q_\alpha$$

where $\Lambda^b = (I - g_\delta^b)^{-1}$; Λ^b is a $n_\delta \times n_\delta$ matrix of input requirements in country b .

If country a produces the same goods in its own country instead of importing them, then the corresponding unit cost function takes the following form

$$(4.17) \quad c_i^a(w^j, p^j) = d_i^a w^a + g_{i\alpha}^a p_\alpha^a + g_{i\gamma}^a p_\gamma^a + g_{i\beta}^a p_\beta^b + q_{i\beta},$$

$$i \in I_\delta, \quad j = a, b$$

or

$$(4.18) \quad c_\delta^a(w^j, p^j) = d^a w^a + g_\alpha^a p_\alpha^a + g_\delta^a p_\delta^a, \quad I_\delta = I_\beta \cup I_\gamma$$

Conditions (4.6) and (4.8) implies that $p_i^a < c_i^a$ for $i \in I_\beta$ and $p_i^a = c_i^a$ for $i \in I_\gamma$. Thus we must have

$$(4.19) \quad c_\delta^a \geq p_\delta^a \quad \text{for all goods in set } I_\delta$$

We therefore can rewrite equation (4.18) as

$$(4.20) \quad p_\delta^a \leq d^a w^a + g_\alpha^a p_\alpha^a + g_\delta^a p_\delta^a$$

Given equation (4.9) it reinforces the following inequality

$$(4.21) \quad p_\delta^a \leq d^b w^a + g_\alpha^b p_\alpha^a + g_\delta^b p_\delta^a$$

By solving for p_δ^a , we find

$$(4.22) \quad p_\delta^a \leq \Lambda^b d^b w^a + \Lambda^b g_\alpha^b p_\alpha^a$$

where $\Lambda^b = (I - g_\delta^b)^{-1}$; Λ^b is of dimension $n_\delta \times n_\delta$.

Premultiplying equation (4.16) by an n_δ -element row vector T_δ yields

$$(4.23) \quad T_\delta p_\delta^b = T_\delta \Lambda^b d^b w^b + T_\delta \Lambda^b g_\alpha^b p_\alpha^a + Q_\alpha^*$$

Where $Q_\alpha^* = T_\delta \Lambda^b g_\alpha^b$. Similarly premultiplying equation (4.22) by a $1 \times n_\delta$ vector T_δ yields

$$(4.24) \quad T_{\delta} p_{\delta}^a \leq T_{\delta} \Lambda^b d^b w^a + T_{\delta} \Lambda^b g_{\alpha}^b p_{\alpha}^a$$

By combining equation (4.24) with equation (4.23) we find another form of restriction on the factor content of bilateral trade patterns as function of the differences in factor prices.⁴³

$$(4.25) \quad T_{\delta} \Lambda^b d^b (w^a - w^b) \geq Q_{\alpha}^* + R_{\delta}$$

where Q_{α}^* is the tariff revenue collected by country b on the total imports of intermediate goods in set I_{α} from country a required both directly and indirectly to produce T_{δ} goods and R_{δ} is the same as before.

Note that all goods in set I_{α} are eliminated from the model underlying equation (4.25). Since d^b indicates direct (unit) factor requirements, $\Lambda^b d^b$ represents (direct plus indirect) home-gross factor requirements. Therefore $T_{\delta} \Lambda^b d^b$ measures actual home-gross factor contents embodied in the goods traded (T_{δ}) with the exporter's techniques of production (here country b). This result suggests that "home-gross" requirements are confirmed as the theoretically

⁴³ Rearranging equation (4.24) and integrating with equation (4.23) it becomes

$$\begin{aligned} T_{\delta} \Lambda^b d^b w^a + T_{\delta} \Lambda^b g_{\alpha}^b p_{\alpha}^b &\geq T_{\delta} p_{\delta}^a = T_{\delta} p_{\delta}^b + T_{\delta} (p_{\delta}^a - p_{\delta}^b) \\ &= T_{\delta} \Lambda^b d^b w^b + T_{\delta} \Lambda^b g_{\alpha}^b p_{\alpha}^a + Q_{\alpha}^* + R_{\delta} \end{aligned}$$

where $R_{\delta} = T_{\delta} (p_{\delta}^a - p_{\delta}^b)$ as before.

By collecting terms it reduces to equation (4.25).

appropriate measure under the general model as well. Condition (4.25) is also consistent with earlier results obtained in the presence of trade barriers such as equations (3.19) and (3.24) in the previous chapter that correlate international factor prices differences with home-gross requirements.

IV. 3 Developing a Feasible Test

Inequality (4.12) gives a basic testable implication of the factor content version of the Heckscher-Ohlin model. This test can be implemented by collecting and processing all the data involved in the condition. In empirical work, however, the data on prices of goods are difficult to obtain due to the large number of goods. On the other hand, estimates of the model underlying equation (4.25) do not require any data on the prices of goods.⁴⁴ Thus condition (4.25) provides another testable implication of the factor content version of the Heckscher-Ohlin theory which corresponds to the proposition derived from the theoretical model. Undertaking a test according to equation (4.25), however, raises another problem. The problem is that it is

⁴⁴ Another method for eliminating the information on goods prices is to trace back to some primary factors. The prices of intermediate goods could be regarded as the prices of primary factor services, with the primary factors being invested at the time the intermediate goods were initially produced with direct inputs only. In this way, any cost of a good could ultimately be traced back to primary factor inputs.

very difficult to find satisfactory data on prices and factor requirements for primary factors in the form of natural resources, whereas labour and capital can be reasonably classified into several categories for which prices and factor requirements can be obtained from available sources.

We thus implement a modified test that is based on condition (4.25) but requires, for natural resources, the data on primary products instead of data on natural resources. The modified test can be explained as follows. First, we decompose each set of goods into two sorts of goods, depending on whether goods are primary products or not, such that $I_{\Sigma} = (I_{\alpha\Sigma}, I_{\beta\Sigma}, I_{\gamma\Sigma})$, $I_{\pi} = (I_{\alpha\pi}, I_{\beta\pi}, I_{\gamma\pi})$ where I_{π} denotes a subset of I that includes all goods which are primary products, and I_{Σ} denotes a subset of all goods in I that are not in set I_{π} .⁴⁵ Similarly let M_{μ} represent a subset (with m_{μ} elements) of M that includes all primary factors except natural resources which constitute the other subset (with m_{ν} elements) of M , M_{ν} . Second, we assume that natural resources are used directly and only in the production of primary products. Thus any good in set I_{Σ} can directly use only factors in set M_{μ} that includes all types of labour and capital.

Under this assumption condition (4.25) can be

⁴⁵ Hence, I_{δ} goods can be decomposed as $I_{\delta} = (I_{\delta\Sigma}, I_{\delta\pi})$, where $I_{\delta\Sigma} = (I_{\beta\Sigma}, I_{\gamma\Sigma})$, and $I_{\delta\pi} = (I_{\beta\pi}, I_{\gamma\pi})$.

ultimately expressed as a function of prices of primary factors except natural resources and prices of primary products. As discussed in the next Chapter, elements of set I_π are small and some information on prices of primary products can be obtained.

Let the I_δ goods input-output coefficient matrix be a $(n_{\delta\Sigma} + n_{\delta\pi}) \times (n_{\delta\Sigma} + n_{\delta\pi})$ matrix decomposed such that

$$(4.26) \quad g_\delta^b = \begin{bmatrix} g_{\delta\Sigma\Sigma}^b & g_{\delta\Sigma\pi}^b \\ g_{\delta\pi\Sigma}^b & g_{\delta\pi\pi}^b \end{bmatrix}$$

where the $n_{\delta\Sigma} \times n_{\delta\Sigma}$ matrix $g_{\delta\Sigma\Sigma}^b$ gives the direct input of $I_{\delta\Sigma}$ goods into one unit output of $I_{\delta\Sigma}$ goods; the $n_{\delta\Sigma} \times n_{\delta\pi}$ matrix $g_{\delta\Sigma\pi}^b$ gives the input of $I_{\delta\pi}$ goods required directly to produce one unit output of $I_{\delta\Sigma}$ goods, etc. Then $\Lambda_{\Sigma\Sigma}^b = (I - g_{\delta\Sigma\Sigma}^b)^{-1}$ is a $n_{\delta\Sigma} \times n_{\delta\Sigma}$ submatrix of Λ^b , showing inputs of $I_{\delta\Sigma}$ goods required both directly and indirectly to produce one unit output of $I_{\delta\Sigma}$ goods; and $\Lambda_{\Sigma\pi}^b = (I - g_{\delta\Sigma\pi}^b)^{-1}$ is a $n_{\delta\Sigma} \times n_{\delta\pi}$ submatrix of Λ^b , indicating direct plus indirect inputs of $I_{\delta\pi}$ goods per unit output of $I_{\delta\Sigma}$ goods, etc. The $(n_{\delta\Sigma} + n_{\delta\pi}) \times (m_\mu + m_\nu)$ direct factor-output matrix d^b is decomposed as

$$(4.27) \quad d^b = \begin{bmatrix} d_{\Sigma\mu}^b & d_{\Sigma\nu}^b \\ d_{\pi\mu}^b & d_{\pi\nu}^b \end{bmatrix}$$

where the $(n_{\delta\Sigma} \times m_\mu)$ matrix $d_{\Sigma\mu}^b$ gives the amounts of factors in set M_μ used directly to produce one unit output

of $I_{\delta\Sigma}$ goods; the $(n_{\delta\Sigma} \times m_\nu)$ matrix $d_{\Sigma\nu}^b$ is a null matrix containing only zeros, etc.

Finally the $1 \times n_\delta$ vector T_δ now can be decomposed into a $1 \times n_{\delta\Sigma}$ vector $T_{\delta\Sigma}$ and a $1 \times n_{\delta\pi}$ vector $T_{\delta\pi}$, respectively, representing the amounts of import of final goods in set I_Σ and in set I_π by country a from country b .

It is then straightforward to show that the pattern of bilateral commodity trade fulfills ⁴⁶

$$(4.28) \quad T_{\delta\Sigma} \Gamma (w_\mu^a - w_\mu^b) + T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b g_{\delta\Sigma\pi}^b (p_{\delta\pi}^a - p_{\delta\pi}^b) + T_{\delta\pi} (p_{\delta\pi}^a - p_{\delta\pi}^b) \geq \Omega$$

where $\Gamma = \Lambda_{\Sigma\Sigma}^b d_{\Sigma\mu}^b$ which specifies a $n_{\delta\Sigma} \cdot m_\mu$ matrix of home-gross factor (except natural resources) requirements for the non-primary goods in set $I_{\delta\Sigma}$; w_μ^j is a $m_\mu \cdot 1$ price vector for M_μ factors in country j ; $p_{\delta\pi}^j$ is a $n_{\delta\pi} \cdot 1$ vector of prices of goods in set $I_{\delta\pi}$ in country j ; and $\Omega = Q_{\alpha\Sigma}^* + R_{\delta\Sigma}$ that represents the sum of the tariff revenues collected on country b 's imports of intermediate inputs in set I_α from country a required both directly and indirectly to produce the non-primary goods in set $I_{\delta\Sigma}$ $\left[Q_{\alpha\Sigma}^* = T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b q_{\alpha\Sigma} \right]$ and on country a 's total imports of the non-primary goods in set $I_{\delta\Sigma}$ from country b $\left[R_{\delta\Sigma} = T_{\delta\Sigma} (p_{\delta\Sigma}^a - p_{\delta\Sigma}^b) \right]$.

Note that the tariff revenue in equation (4.25) is expressed for all T_δ goods ($T_{\delta\Sigma}$ plus $T_{\delta\pi}$), while the

⁴⁶See Appendix E for a full description of equation (4.28).

tariff revenue in equation (4.28) is expressed for only $T_{\delta\Sigma}$ goods. The difference in the total tariff revenues between equations (4.25) and (4.28) is due to a difference in the categories of goods represented. Since the second and third terms in equation (4.28) include some tariff which is levied on $T_{\delta\pi}$ goods, if we account for the tariff, then we have the same amount of tariff revenues in the both equations. This point is fully discussed in Appendix E.

The model underlying equation (4.28) essentially combines equation (4.12) with equation (4.25) so as to overcome the problem of data availability without any significant change in the proposition. As a result condition (4.28) has the convenient property of not needing data on either direct requirements or prices of natural resources. Even the measures in equation (4.28), however, raises an empirical problem in that the readily available data provides estimates of both input and factor requirements in the form of amounts per dollar's worth of output instead of per unit of output. We deal with the problem as follows.

Multiplying each element of a column vector of input requirements by the price of corresponding goods with the vector, we have a dollars' worth of intermediate inputs per unit output of the good, and then dividing each entry of a row vector by the price of the corresponding goods with the vector, we obtain values of intermediate inputs per dollar's worth of output of the good. Letting $\bar{g}_{\delta}^b$ represent the

matrix of direct input coefficients per dollar's worth of I_δ goods in country b , we have

$$(4.29) \quad \bar{g}_\delta^b = (\hat{p}_\delta^b)^{-1} g_\delta^b \hat{p}_\delta^b$$

where a circumflex ($\hat{}$) over the symbol for a vector indicates a square matrix in which the elements of the vector appear on the main diagonal while zeros are entered elsewhere.⁴⁷ The matrix $\bar{g}_\delta^b$ is then partitioned to obtain the $n_{\delta\Sigma} \times n_{\delta\Sigma}$ submatrix $\bar{g}_{\delta\Sigma\Sigma}^b = (\hat{p}_{\delta\Sigma}^b)^{-1} g_{\delta\Sigma\Sigma}^b \hat{p}_{\delta\Sigma}^b$ and the $n_{\delta\Sigma} \times n_{\delta\pi}$ submatrix $\bar{g}_{\delta\Sigma\pi}^b = (\hat{p}_{\delta\Sigma}^b)^{-1} g_{\delta\Sigma\pi}^b \hat{p}_{\delta\pi}^b$. Correspondingly, $\Lambda^b = (I - \bar{g}_\delta^b)^{-1}$ is defined as the matrix of input requirements (in dollars) per dollar's worth of I_δ goods in country b , and then partitioned to obtain the $n_{\delta\Sigma} \times n_{\delta\Sigma}$ submatrix $\Lambda_{\Sigma\Sigma}^b = (I - \bar{g}_{\delta\Sigma\Sigma}^b)^{-1}$. Similarly, a $n_{\delta\Sigma} \times m_\mu$ matrix $d_{\Sigma\mu}^b$ of factor requirements per dollar's worth of output of $I_{\delta\Sigma}$ goods is determined as

$$(4.30) \quad d_{\Sigma\mu}^b = (\hat{p}_{\delta\Sigma}^b)^{-1} d_{\Sigma\mu}^b$$

All these matrices can be readily derived from available data sources.

The import data are available only in the form of dollar amounts

⁴⁷ Note that $\bar{g}$ is the transpose of the Leontief direct input coefficient matrix. Thus $(I - \bar{g})^{-1}$ is the transpose of the Leontief inverse matrix.^δ

$$(4.31) \quad \mathbb{T}_{\delta} = \mathbb{T}_{\delta} \hat{\mathbb{P}}_{\delta}^b$$

The vector $\mathbb{T}_{\delta}$ is then decomposed into the $1 \times n_{\delta\Sigma}$ vector $\mathbb{T}_{\delta\Sigma} = \mathbb{T}_{\delta\Sigma} \hat{\mathbb{P}}_{\delta\Sigma}^b$ and the $1 \times n_{\delta\pi}$ vector $\mathbb{T}_{\delta\pi} = \mathbb{T}_{\delta\pi} \hat{\mathbb{P}}_{\delta\pi}^b$. Hence, condition (4.28) can be rewritten in terms of these matrices and vector as follows:

$$(4.32) \quad \mathbb{T}_{\delta\Sigma} \mathbb{I} (w_{\mu}^a - w_{\mu}^b) + \mathbb{T}_{\delta\Sigma} \lambda_{\Sigma\Sigma}^b \tilde{g}_{\delta\Sigma\pi}^b \left[(\hat{\mathbb{P}}_{\delta\pi}^b)^{-1} p_{\delta\pi}^a - 1 \right] \\ + \mathbb{T}_{\delta\pi} \left[(\hat{\mathbb{P}}_{\delta\pi}^b)^{-1} p_{\delta\pi}^a - 1 \right] \geq \Omega$$

where $\mathbb{I} = \lambda_{\Sigma\Sigma}^b d_{\Sigma\mu}^b$ and $\mathbf{1}$ is a unit vector. Our modified test can be implemented by estimating the model underlying equation (4.32).

CHAPTER V

TESTS OF THE MODEL

V.1 Measurement of Variables

This chapter tests the proposition defined by equation (4.32). Equation (4.32) specifies condition on the factor content pattern of bilateral trade that must be satisfied by post-trade observations consistent with the general Heckscher-Ohlin theory embodied in the assumption of the theoretical model. Testing this proposition requires measures of the input requirements $(\Lambda_{\Sigma\Sigma}^b)$, the direct factor requirements $(d_{\Sigma\pi}^b)$, the import vector (T_δ) , the tariff revenue (Ω) , the bilateral factor price differentials $(w_\mu^a - w_\mu^b)$, and the bilateral primary-good price ratios $\left[(\hat{p}_{\delta\pi}^b)^{-1} p_{\delta\pi}^a \right]$. Each of these measures is discussed below.

We restrict our test of the factor content pattern of bilateral trade to four countries for which reasonably consistent cross-country data on factor prices by occupational groupings are available. The four countries are the United States, Canada, the United Kingdom and Japan. We choose the year 1980 because this is the most recent year for which a complete data set is available. We undertake three bilateral tests selecting the United States as a base country (in our model country b) because of greater

availability of data on input requirements (of intermediate goods and primary factors).

We use an empirical model with twenty six industries/commodities and eight primary factors excluding natural resources. The list of twenty six commodities includes three primary products, which constitute set I_{π} , and the remaining twenty three commodities, which constitute set I_{Σ} . The eight factors (M_{μ}) consist of seven categories of labour (based on occupational classification) and one category of capital defined as follows:⁴⁸

1. Professional and technical workers
2. Managerial and administrative workers
3. Sales workers
4. Clerical workers
5. Farming, fishery, and forestry workers
6. Service workers
7. Residual workers (mainly unskilled workers)
8. Net mid-year capital stock valued at current prices

The empirical model uses a base of 1980 data on trade, employment, capital stock, and the 85-order input-output tables for the United States, plus factor prices, Primary goods prices, and tariff revenues for all countries. A detailed discussion of the data is presented in Appendix G. The aggregation codes for the 85 input-output sectors to the

⁴⁸ These categories are similar to those used by Brecher and Choudhri (1988).

26 sectors adopted here are given in Table G.2 in Appendix G.

A. Input Requirements Matrix: A^b

We use a commodity by industry input-output model to account for the possibility that an industry produces more than one good.⁴⁹ In this framework, the data is available in the form of USE matrix, representing amounts of requirements of (intermediate) goods by different industries, and MAKE matrix, representing amounts of production of goods by each industry. In order to relate this data to the theoretical model underlying equation (4.32), we assume commodity-based technology which implies that a commodity has the same input requirements regardless of which industry produces it.⁵⁰ We use this assumption to derive⁵¹

$$(5.1) \quad Q = \left(I - BC^{-1} \right)^{-1} F$$

⁴⁹ The general input-output model is laid out in Miller and Blair (1985) among others. For a detailed input-output structure for the U.S., see Survey of Current Business, May 1984.

⁵⁰ The commodity by industry model is to deal with the problem of secondary production. An alternative assumption is an industry-based technology, which implies that the input requirements of commodities depends upon the industry in which they are produced. The two technology assumptions are different treatments of the same problem. For the discussion on which technology assumption might be preferred, see Stone (1961) or Bulmer and Thomas (1982) cited in Miller and Blair (1985).

⁵¹ Appendix F provides the matrix algebra underlying the derivation of the total requirements from the U.S. input-output tables.

where $\mathbf{0}$ is a column vector in which each entry shows the total amount of the output of each commodity; $\mathbf{I}$ is the unit matrix; $\mathbf{B}$ is a commodity-by-industry matrix in which entries in each column show the amount of a commodity used by an industry per dollar of output of that industry; $\mathbf{C}$ is a commodity-by-industry matrix in which a column gives an industry's output (in dollars) of different commodities as a proportion of its total output; and $\mathbf{F}$ is a column vector in which each entry shows the total final demand purchases for each commodity.

The matrix $(\mathbf{I} - \mathbf{BC}^{-1})^{-1}$ is known as the commodity-by-commodity total requirements matrix; the ij th element of this matrix gives the dollars' worth of commodity i 's output required to deliver a dollar's worth of commodity j to final demand. Since all goods in set I_α are eliminated from the model underlying equation (4.32), estimates of $\Lambda_{\Sigma\Sigma}^b$ according to equation (5.1) depend on the specification of I_α goods imported but not produced in country b .

An imported commodity is treated in one of two ways in the 1980 U.S. input-output table. Those that are comparable to commodities which are domestically produced (competitive imports) are represented in column 95 of the use table. Other commodities, those that are not comparable to commodities produced domestically (noncompetitive imports), are contained in row 80 of the use table. This distinction is that competitive imports are handled by adding

transactions to the domestic transactions matrix as if they were domestically produced, while noncompetitive imports are assigned to a new industry category.

One possible approach is to assume perfect substitutability between home goods and competitive imports, so that λ^b excludes only noncompetitive imports. However, this trade-theoretic assumption of perfect substitutability is generally found to be not workable in empirically based trade models [see, for example, Deardorff and Stern (1986)].⁵²

Thus as an alternative approach we adopt the Armington (1969) assumption that goods are differentiated by country of origin. Under this assumption imports and domestic goods are not perfect substitutes and thus we have to exclude competitive imports from the intermediate transaction matrix, that is, the use matrix in the commodity-by-industry model. It follows that we have to subtract each competitive import good used by different industries from the corresponding row of the use matrix, but the available data make this exercise impossible. Given the information in the U.S. input-output tables, one possible way is to assume that each user of the commodity divides his uses between

⁵²On the one hand, such perfect substitutability is inconsistent with the empirical fact that countries have both exports and imports in any given industry. On the other hand, perfect substitutability between domestic and foreign goods is inconsistent with the empirically observed elasticities that seem to prevail in international trade [see, Deardorff and Stern (ch.10, 1985)].

domestic production and imports in the same proportions. Following this procedure $\hat{\Lambda}^b$ is calculated as follows.

This import share assumption implies

$$(5.2) \quad M = \hat{\theta} (BX + D + I + G)$$

where $\hat{\theta}$ is a diagonal matrix of coefficients whose elements are calculated as the ratios of imports (M) to use which is defined as $(BX + D + I + G)$; D, I, and G are personal consumption expenditures, private domestic investment, and government purchases in final demand categories, respectively.⁵³

By substituting equation (5.2) into equation (5.1) where $F = D + I + G + E - M$, we obtain the open output determination model which makes an allowance for import leakage out of intermediate as well as final demand as follows

$$(5.3) \quad Q = \left[I - (I - \hat{\theta}) BC^{-1} \right]^{-1} [(I - \hat{\theta})(D + I + G) + E]$$

where E is domestic exports in final demand categories. Thus if we denote the Leontief input-output coefficient matrix by A, we find that $A = (I - \hat{\theta}) BC^{-1}$ for a commodity-by-commodity table.⁵⁴ Since the matrix $\tilde{g}_s^b$ is the

⁵³ It should be noted that this import share assumption does not account for imports which may be indirectly embodied in domestic exports.

⁵⁴ In customary input-output terminology, gross output (X)

transpose of A , we have ⁵⁵

$$(5.4) \quad \tilde{g}_{\delta}^b = (I - \hat{\theta}) (C')^{-1} B'$$

The matrix $\tilde{g}_{\delta}^b$ is used to derive the commodity-by-commodity modified "home-gross" input requirements matrix, Λ^b , in which the ij th element gives a dollars' worth of commodity i required (both directly and indirectly, but excluding foreign intermediate inputs) to deliver one dollar's worth of commodity j to final demand.

$$(5.5) \quad \Lambda^b = [I - \tilde{g}_{\delta}^b]^{-1}$$

The matrix Λ^b is then partitioned to obtain the 23×23 $\Lambda_{\Sigma\Sigma}^b$ submatrix. The input requirements matrix also excludes noncompetitive imports (row 80) as well as scrap and used goods (row 81).

B. Direct Factor Requirements Matrix : $\bar{d}^b$

The industry-by-factor matrix $\bar{d}^b$ of direct

and final demand (F) are connected through the relationship: $X = (I - A)^{-1} F$ in which each column of matrix A shows the amount of output required from each sector to produce one dollar of product from a given industry, while each row of matrix $\tilde{g}_{\delta}^b$ here does.

⁵⁵Thus, a row of B' shows requirements (in dollars) of different commodities for producing a dollar's worth of industry output, while a row of C' shows an industry's output (in dollars) of different commodities as a proportion of its total output.

requirements, indicates how much direct input of each of eight primary factors is required to produce a dollar's worth of output within each of 26 industries. This matrix can be calculated for the eight factors (7 labour and capital categories) by division of each factor for each industry by the respective industry's output.

Labour Input Requirements

The seven labour skill categories are based on the two digit level of the 1980 Standard Occupational Classification (SOC), published by the U.S. Department of Commerce.⁵⁶ Labour input in each occupational group by industry is gathered from the occupation by industry volume of the U.S. Census of Population (1980).⁵⁷ Since the coverage of the Census data is slightly different from that of the input-output data, the Census data on labour input is adjusted in such a way that the occupational distributions are benchmarked to total labour inputs data published in the National Income and Product Accounts of the United States, 1929-82.⁵⁸ Data on gross output by industry, given in

⁵⁶ The composition of this group is described in Table G.4 in Appendix G.

⁵⁷ The correspondence between the detailed industries of the Census and the Input-Output industries is very close; discrepancies are handled by reference to the SIC code referred to above.

⁵⁸ The U.S. employment by input-output classification is not directly available for the year of 1980. However, the employment by industry data published in NIPA is classified

millions of dollars, are directly available from the "Make" matrix of the U.S. input-output model. Thus direct labour input is measured in terms of number of workers per million dollars of output.⁵⁹

Capital Input Requirements

Data on capital stock in each input-output industry are obtained directly from the Bureau of Economic Analysis. These data contain estimates of net stock for Equipment and Structure in millions of dollars at current price.⁶⁰ We use the average of capital equipment and structure values as estimated at the start and end of the 1980 year. Each industry capital stock is then divided by gross output in millions of dollars in that same industry to calculate the capital-output ratio in each sector.⁶¹

in very similar way as the input-output industry classification. Table G.2 in Appendix G maps the industry classification to our input-output industries.

⁵⁹ For example, if the occupational composition data indicate that 1% of workers in a given industry are professional and technical workers, and the employment by industry data indicate that there are 100,000 workers in the industry, we assume that there are 1,000 professional and technical workers in the industry. If the industry has 100 million dollars of output, the direct requirement of such workers is 10 professionals per million dollars of output.

⁶⁰ For equipment and structures the BEA employs the perpetual inventory method, using investment data from the U.S. national product accounts, and assuming that the capital stock is a weighted sum of past investments, with weights given by relative efficiencies of capital goods of different ages. For alternative measures of capital input see the Bureau of Labour Statistics (1983), Denison (1985), Jorgenson (1980), and Kendrick (1983).

⁶¹ There are minor linkage problems between this classification system and ours. Table G.2 in Appendix G

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PIONEERS IN METHYLENE BLUE TESTING SINCE 1974

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Once direct factor requirements per dollar of output are prepared for each industry, we can convert dimension industry-by-factor ($\bar{d}^b$) into dimension commodity-by-factor ($\bar{d}^b$), using the industry output proportions matrix, C .⁶² Table G. 9 and G. 10 in Appendix G provides $\bar{d}^b$ and Λ^b .

C. Factor Prices : w_μ^a and w_μ^b

As discussed before, the 8×1 factor prices vector w_μ^j consists of the price of each type of labour service and the price of the service (gross rental rate) for capital employed in country j , respectively. Estimates of these factor prices are discussed below.

Price of Labour Service

For the seven categories of labour, we measure the price of labour services by the average value of the corresponding wage and salary for all industries. We define wages and salaries as covering all payments to wage earners and salaried employees on a gross (before taxes etc.) basis. The wage and salary data for the four countries are obtained from the Census of Population (1980): Earnings by Occupation for the United States, the Census of Canada (1981): Employment Income by Occupation for Canada, the

contains a mapping of capital stock industry aggregation into our 26-sector aggregation.

⁶² A 26×8 commodity-by-factor matrix of direct requirements is calculated as $\bar{d}^b = (C')^{-1} \bar{d}^b$. The $\bar{d}^b$ matrix is also partitioned to obtain the 23×8 $\bar{d}_{\Sigma\mu}^b$ submatrix.

New Earnings Survey (1980): Analyses by Occupation for the United Kingdom, and the Japan Statistical Yearbook (1982) for Japan. The wage and salary data from each source are reclassified in conformity with our occupational groupings.⁶³ Since the survey reference pay-period is slightly different between countries, the data are also adjusted to represent 1980 figures.

Unfortunately, complete wage data are not available for Japan. The Japan Statistical Yearbook (1982) probably provides the best currently available data on the wage rate by occupation in the year 1980 in Japan.⁶⁴ The Yearbook data, however, suffer from a few important limitations. First, the Yearbook reports no information on the wage rate by occupational groupings 2 and 5. Second, the yearbook contains relatively a few subcategories of group 1. For group 1, the comparison of wage rates between Japan and the United States is based on some limited number of subcategories. Utilizing the available data we match wage rates of ten occupations belonging to group 1 in the Yearbook with the corresponding occupations in the United States Census. This method, however, is not available for groups 2 and 5. For these groups, as a last resort, we use

⁶³ They are all reported by sex - however the total male and female populations are given for each group so that the average can be computed for the total of both sexes.

⁶⁴ Another potential source on earnings by occupation in Japan is ILO Bulletin of Labour Statistics: October Inquiry Results which is annually published by United Nations. This publication can provide a supplementary information, but it is available from 1983 for Japan.

aggregate wage rates in Japan and the United States derived by Jorgenson and Kuroda (1990). As noted, we do not have reliable estimates for these groups. Accordingly, the tests discussed below include a sensitivity analysis with respect to these group's wages.

Table V.1 shows the data on earnings in each country. A full description of sources and methods for compiling the data may be found in Section 2 in Appendix G.

Table V.1

Average Wages and Salaries by Occupational Groupings, 1980

Occupational Groupings	U.S. Dollars			
	Wages and Salaries			
	U S	CAN	U K	JAP
G 1	17,403	18,889	16,202	11,121
G 2	23,817	22,998	18,722	14,365*
G 3	13,821	15,982	11,324	8,008
G 4	10,539	11,849	10,448	6,776
G 5	10,674	12,506	10,763	6,438*
G 6	7,346	12,353	11,341	7,682
G 7	16,558	17,715	13,429	9,401

* They are done by applying the labour input price index for the U.S. and Japan reported by Jorgenson and Kuroda (1990) to the U.S. wage rate.

Sources: U.S. - Census of Population:
Occupation by Industry 1980

Canada - Census of Canada 1981: Worked in 1980 -
Employment Income by Occupation

U.K. - New Earnings Survey 1980 and 1981:
Part D Analyses by Occupation

Japan - Japan Statistical Yearbook 1982: Table 299

Price of Capital Service

In the case of capital, a different treatment is required because in contrast to labour input which is measured in person years capital input is measured in dollars at home-country price. The first term in condition (4.32) relating to capital can be rewritten as

$$(5.6) \quad T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b \left(a_{\Sigma\mu k}^b p_{\mu k}^b \right) \left(\frac{w_{\mu k}^a}{p_{\mu k}^b} - \frac{w_{\mu k}^b}{p_{\mu k}^b} \right)$$

where $p_{\mu k}^b$ denotes the price of capital stock in country b and $w_{\mu k}^j$ denotes the price of the service (gross rental rate) for capital employed in country j , $j = a, b$. The term $a_{\Sigma\mu k}^b p_{\mu k}^b$ is the direct requirement of capital in dollars using country b 's prices (estimations discussed in Section 1.B). The first term in the last bracket can be expressed as

$$(5.7) \quad \frac{w_{\mu k}^a}{p_{\mu k}^b} = \frac{p_{\mu k}^a}{p_{\mu k}^b} \frac{w_{\mu k}^a}{p_{\mu k}^a}$$

The ratio $\frac{p_{\mu k}^a}{p_{\mu k}^b}$ represents the purchasing power parity for the capital input (measured in US dollar).⁶⁵ Estimates of these ratios are obtained from a report of real expenditures for OECD countries based on Purchasing Power Parities

⁶⁵ The relative price of the capital input in country a and country b represents the ratio of the number of U.S. dollars required in country a to purchase an amount of the capital costing one dollar in the United States.

calculated for 1980 undertaken by OECD.⁶⁶ The term $\frac{w_{\mu k}^j}{p_{\mu k}^j}$ represents the rate of return on capital in country j , $j = a, b$. This ratio can be estimated by dividing the total return to capital by the value of capital stock.

Never easy to define analytically and derive empirically, however, rates of return have always been a problem in applied economic work and this paper is no exception. In estimating the rate of return on capital we follow a conventional definition of inflation-adjusted rate of return. The denominator, that is, capital employed, is the current value of plant, equipment, and inventories, whereas the numerator, that is, operating income, is inflation-adjusted profits plus net interest payments.⁶⁷

Estimates of the rate of return on capital are obtained from papers in a collective volume (edited by Holland 1984).⁶⁸ Each paper in this volume measures the rate of

⁶⁶ Michael Ward, Purchasing Power Parities and Real Expenditures in the OECD, OECD, 1985.

⁶⁷ More broadly conceived the capital stock includes net non-interest-bearing monetary assets, land, and even the results of research and development and advertising as well as plant, equipment, and inventories. The numerator could also include (in addition to inflation-adjusted profits and net interest paid) holding gains (or losses), that is, increases (or decreases) in the value of company assets over and above the change in a standard (generally consumption-based) deflator.

⁶⁸ The estimates of rate of return for nonfinancial corporations derived from national accounts are described in Holland and Myers, "Trends in Corporate Profitability and Capital Costs in the United States"; in Williams, "The Profitability of United Kingdom Industrial and Commercial

return for a specific country. U.S. rate of return is given by Holland and Myers (1984). U.K. rate of return is given by Williams (1984). Japanese rate of return given by Wakasugi et al (1984) is recalculated in this paper in a method conforming to our definition. While a closer examination of each country's estimates will indicate that they differ in details of definition and industry coverage, nonetheless, we consider them sufficiently similar to permit broad comparisons of rates of return across countries. Canada's estimated in the same source are not available for 1980. A comparable rate of return for 1980 is directly obtained from Statistics Canada.⁶⁹ This rate, however, is not adjusted for inflation. For purpose of comparison, therefore, the United States rate should also be unadjusted. We obtain the corresponding unadjusted rate for the United States from the source cited earlier (Holland and Myers 1984). This rate of return would depend on the inflation rate. However, as the inflation rates in the United States and Canada are similar we expect that the relative unadjusted rates would not be too different from adjusted rates. We thus use these inflation-unadjusted rates for the case of the United States and Canada.

Companies 1963-1981"; and in Wakasugi et al, "Measuring the Profitability of the Nonfinancial Sector in Japan", in Measuring Profitability and Capital Costs, edited by Holland (1984).

⁶⁹ Mizard Salem of the Input-Output Division of Statistics Canada kindly provides the rate of return on capital for 1980 estimated based on our definition.

Estimates of the rate of return on capital employed for 1980 are given Table V.2.

Table V.2
Rate of Return on Capital Employed for 1980

	US	CAN	UK	JAP
$w_{\mu k}^j / p_{\mu k}^j$	0.078 (0.172) *	- (0.11885) *	0.036	0.1186
$p_{\mu k}^j / p_{\mu k}^{us**}$	1.0	0.9274	1.5512	1.1797
$w_{\mu k}^j / p_{\mu k}^{us}$	0.078 (0.172) *	0.1102 *	0.0558	0.1399

* These rates of return are not adjusted for inflation.

** Purchasing power parity for gross fixed capital formation between a specified pair of countries (converted to US dollar).

D. Primary Product Prices: p^a and p^b

The term $(\bar{p}_{\delta\pi}^b)^{-1} p_{\delta\pi}^a$ in condition (4.32) is the ratio of prices of primary products in the two countries.⁷⁰ Primary products are divided into three commodity groups: (1) Agriculture, Forestry, and Fishing (2) Mining and Quarrying, and (3) Mineral Fuels. From available data it is difficult to construct aggregate price ratios for each group. It is possible, however, to estimate price ratios for a number of individual products in each group. We thus use a simple or a weighted average of these ratios.

For the first commodity group we employ the prices of selected agricultural products in the United States, Canada, and the United Kingdom, which are taken from Prices of Agricultural Products and Selected Inputs in Europe and North America 1981/82, UN 1983. We then compute the average price ratio of the selected products.⁷¹ Unfortunately, no reliable data on Japan are available. Hence we construct the price ratio using import and export prices after comparing the trade volumes of the selected agricultural products between the United States and Japan (See Appendix G.). Prices of selected mining products are taken from the Minerals Yearbook 1980, and used to

⁷⁰ The ratio of less than one can be considered cheaper in country a than in country b. The opposite is true with a ratio of more than one.

⁷¹ They are unweighted average price ratio. We don't have good data on the consumption of the commodities so that weighted average prices are not feasible.

compute the average price ratio of the second commodity group. For the last commodity group the prices of oil and natural gas for industry are taken from Energy Prices and Taxes 1990, OECD 1991. We then compute weighted average price ratios of light fuel oil, heavy fuel oil, and natural gas using data on the consumption of those products obtained from the same source.

As noted, we do not have good estimates of these price ratios for primary products. In the tests discussed below, therefore, we conduct the sensitivity analysis with respect to our proxy estimates. The ratios of prices of primary products are summarized in Table V.3. All basic data used to derive these ratios are provided in Tables 17 - 20 in Appendix G.

Table V.3
Ratio of Prices of Primary Products, 1980

Industry Number	CAN / US	U K / US	JAP / US
1	* 1.100	1.593	1.297
2	** 1.005	1.006	1.25
3	*** 0.658	1.513	1.768

* Unweighted average price ratio of selected agricultural products.

** Unweighted average price ratio of ferrous and nonferrous metal.

*** Weighed average price ratio of light fuel oil, heavy fuel oil and natural gas for industry.

E. Trade Data: $\tilde{T}$

The terms $T_{\delta\Sigma}$ and $T_{\delta\pi}$ in condition (4.32) are, respectively, the 1×23 and the 1×3 vector where the elements denote the total value of imports of final goods by country a from country b . Data are collected on the exports of the United States to each country in 1980, at the 2-digit level of the Standard Industrial Classification. All trade flow data are derived from U.S. Exports. Domestic Merchandise, SIC-Based Products by World Areas, Bureau of the Census 1985 and aggregated into our 26-sector model. Table G.21 in Appendix G shows the data on imports by input-output sector.

F. Tariff Revenues: Ω

Finally, the last term in condition (4.23) represents the cost of trade barriers. In the calculation of the cost of trade barriers, we have a few problems. First, as discussed in Chapter 3, trade barriers may consist of tariff, nontariff barriers which have tariff equivalents, or transport costs. As estimates of nontariff barriers and transport costs are not easily available, we only include the revenue of import tariff. This would lead to underestimate the cost of trade barriers.⁷² Next, published

⁷² The inclusion of subsidies to exports would have reducing effects on the estimates of Ω . However, these tend to be small. If subsidies to exports are not so large as to outweigh the cost of trade barriers, the value of Ω must be at least some positive figure.

data on tariff revenue are not sufficiently disaggregated to estimate the term Ω precisely. The term Ω is the sum of $Q_{\alpha\Sigma}^*$ and $R_{\delta\Sigma}$, where $Q_{\alpha\Sigma}^*$ is the tariff revenue collected on country b 's imports of intermediate inputs (in set I_{α}) from country a used to produce non-primary exports to country a , and $R_{\delta\Sigma}$ is the tariff revenue collected on country a 's total imports of the non-primary goods produced in country b .

For the term $Q_{\alpha\Sigma}^*$, therefore, we multiply the United States total customs and import duties by the ratio of its noncompetitive imports used as intermediate inputs to its total imports, by the ratio of its exports of non-primary goods to its total production and by the ratio of its exports to country a to its total exports. For the next term $R_{\delta\Sigma}$ we multiply each country's total customs and import duties by the ratio of its imports from the United States to its total imports from the world and by the ratio of its imports of non-primary goods to its total imports (for a full description, see Table G.23 in Appendix G).

All tariff revenue Statistics are taken from Revenue Statistics of OECD Member Countries, OECD 1987 and adjusted to refer to the calendar year, while trade statistics in the country destination are taken from OECD Monthly Statistics of Foreign Trade, OECD 1983. The 1980 U.S. Use (input) table provides the information on noncompetitive imports that are used as intermediate inputs and final demands separately. Table V.4 presents the

estimates of the total tariff revenues for each pair of countries.

Table V.4
Total Tariff Revenues, 1980

Bilateral Trade	$R_{\delta\Sigma}$ $Q_{\alpha\Sigma}^*$ (in Millions of US Dollar)
CAN - US	1,711.401 2.65
UK - US	297.126 0.96
JAP - US	401.048 1.55

Source: Table G.23 in Appendix G.

V.2 Results

In this section we test whether the inequality given by condition (4.32) is violated. Given the estimates of the above variables, implementation of this test is straight forward.⁷³ The results of our test for each pair of countries is reported in Table V.5.

Table V.5

Results of Testing the Factor Content Version of HO Theory

(US Dollar)					
Country	First Term	Second Term	Third Term	Total*	Ω^{**}
US - CAN	9.8E+08	-310	-151	9.8×10^8	1.7×10^9
US - UK	-7.0E+08	334	373	-7.0×10^8	0.3×10^9
US - JAP	-2.1E+09	875	2,057	-2.1×10^9	0.4×10^9

$$\text{First Term} = T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b d_{\Sigma\mu}^b \left(w_{\mu}^a - w_{\mu}^b \right)$$

$$\text{Second Term} = T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b \bar{g}_{\delta\Sigma\mu}^b \left(p_{\delta\pi}^a / p_{\delta\pi}^b - 1 \right)$$

$$\text{Third Term} = T_{\delta\pi} \left(p_{\delta\pi}^a / p_{\delta\pi}^b - 1 \right)$$

* Total = First Term + Second Term + Third Term

** $\Omega = Q_{\alpha\Sigma}^* + R_{\delta\Sigma}$ (source: Table V.4)

⁷³ The computer program used to calculate equation (4.32) is MathCAD Version 2.0 (See Appendix H).

This table reports the estimates of the three terms on the left hand side of equation (4.32) as well as the total of these terms. For all three cases the value of second and third terms tends to be small so that the value of total is dominated by the first term.

The maintained hypothesis is that the commodity pattern of bilateral trade satisfies condition (4.32), that is, the total value of the left hand side of equation (4.32) exceeds the (non-negative) value of the right hand side. As Table V.5 shows, for United States - United Kingdom and United States - Japan, the value of left hand side (Total) is less than zero and clearly below the value of right hand side (Ω). For United States - Canada, the estimates of left hand side is positive but much less than the estimates of Ω . This means that estimates of factor content of trade in goods differ significantly from predicted value. Note, however, that the result of the United States and Canada case is less clearcut due to the difficulty of estimating the cost of trade barriers (Ω). If we assume that either selected tariff revenues are sufficiently low or all trade barriers are identically zero, the test to United States - Canada could be favorable to the Heckscher-Ohlin-Vanek model.

It is possible that our estimates are due to vague data on the wage rates by Group 1, 2, and 5 in Japan and the primary products prices as discussed earlier. We thus experimented with how our results would have changed if the

data had looked different. If for these parameters we use arbitrary values such that the upper bound values are set at 25% more and the lower bound values are set at 25% less than the existing values, respectively, all terms of equation (4.32) and thus all terms in Table V.5 would be effected. The recalculations of the model for each pair of countries with these upper and lower bound values produce few changes in the estimated results. The results of these exercises are summarized in Table V.6.

Table V.6
Sensitivity of Results to Parameters

Country		First Term	Second Term	Third Term	Total*	Ω^{**}
US - CAN	L	9.794×10^8	-645	-766	9.8×10^8	1.8×10^9
	U	9.794×10^8	26	464	9.8×10^8	
US - UK	L	-6.955×10^8	177	48	-7.0×10^8	3.2×10^8
	U	-6.955×10^8	492	697	-7.0×10^8	
US - JAP	L	-2.334×10^9	485	-73	-2.3×10^9	4.3×10^8
	U	-1.915×10^9	1.265×10^3	4.188×10^3	-1.9×10^9	

* Total = First Term + Second Term + Third Term

** $\Omega = Q_{\alpha\Sigma}^* + R_{\delta\Sigma}$

As Table V.6 shows, our overall results do not support the factor content prediction of the Heckscher-Ohlin theory given by equation (4.32). We therefore remain uncertain about the exact source of the departure from the influential theory.

CHAPTER VI

CONCLUSION

This study extends Helpman's factor content test of the Heckscher-Ohlin trade theory to a model with both intermediate goods and trade impediments. In this model, an important issue is whether the calculation of factor contents should be based on only direct or gross (direct plus indirect) factor requirements. We show that neither direct nor gross requirements are the appropriate measure for a test of this general model. One contribution of this study is the development of a new measurement which is referred to as "home-gross" factor requirements. We establish that the home-gross requirements always provide a valid measure of factor content of trade.

In this study, we also develop a test based on the new measurement in a form that can be implemented empirically. We then applied this test to United States - Canada, United States - United Kingdom, and United States - Japan, using a data set constructed specially for this purpose. We find, for all three of these pairs of countries, that estimates of factor content of trade in goods differ significantly from predicted values. The data limitation, however, made it difficult for us to obtain the reliable measures of some

variables used in the model. This problem was especially serious in the case of United States and Canada. We therefore conducted sensitivity analysis to allow variations in certain variables which were suspected of measurement error. Our results were robust under these sensitivity tests.

Empirical tests of the Heckscher-Ohlin-Vanek theory have usually relied on factor contents of net trade, although the Helpman test can be formulated in terms of either gross or net imports.⁷⁴ The test based on net trade seems to require the data on input requirements of intermediate goods and primary factors for both countries. Unfortunately, these data are only available for the United States and thereby lead to the test based on gross trade. Our test according to equation (4.32), however, can be easily extended to the test based on net trade by adding the estimates of the factor contents of gross imports from country *a* (Canada, the United Kingdom, or Japan) by country *b* (the United States) with country *a*'s techniques of production.

The overall failure of this test indicates that factor price differences alone, given trade barriers, can not

⁷⁴ The Helpman's test (2.12) is $(w^a - w^b) T^{ab} \geq 0$
 and by symmetry $(w^b - w^a) T^{ba} \geq 0$.
 Combining them yields $(w^a - w^b) (T_v^{ab} - T_v^{ba}) \geq 0$.
 The term, $(T_v^{ab} - T_v^{ba})$, represents net import vector by
 country *a* from country *b* for factor contents.

account for the empirical inadequacy of the Heckscher-Ohlin-Vanek theory. We thus remain faced with the question of which of the other assumptions of the theory might be the source of the problem. The question points towards alternative hypotheses based on specific departures from the Heckscher-Ohlin-Vanek assumptions regarding technology and market structure.

Recently the Krugman-Helpman model using monopolistic competition has provided a well-known extension of the Heckscher-Ohlin theory into the realm of imperfect competition and scale economies.⁷⁵ In a recent book, Helpman and Krugman (1985) show that their model with free trade but unequal factor prices yields predictions about the factor content of trade similar to those of the Heckscher-Ohlin-Vanek model.⁷⁶ Since empirical evidence has continued to reject free trade versions of the Heckscher-Ohlin-Vanek model, this implies that the Krugman-Helpman model could be rejected as well. It would be interesting to see, however, how the factor content pattern of trade would be influenced by the inclusion of trade barriers in the monopolistic competition model. This

⁷⁵ For the theoretical developments of monopolistic competition model see Krugman (1979), Lancaster (1980), Dixit and Norman (1980, ch.9), and Helpman (1981, 1984b).

⁷⁶ With the assumption of homothetic technology and Spence (1976) - Dixit and Stiglitz (1977) type of preferences for varieties of differentiated products the Krugman-Helpman model can yield the restrictions on the factor content of bilateral trade flows that were derived in Helpman (1984a) and in Chapter II (equation 2.12) of this paper.

will be the topic of further research.

APPENDIX A

Effective Rate of Protection

The basis concept of "effective rate of protection" arose in order to provide a measure of protection afforded by the complete trade tax structure to each industry in the context of a model involving imported intermediate inputs. Industries are influenced not only by the tariff on the goods they produce but also the tariff on the intermediate inputs they import.

In order to calculate effective rate of protection we follow the model developed by Markusen and Melvin (1988, ch.17). Since total cost is equal to total revenue, we can write, for the i^{th} industry,

$$(A.1) \quad t_i^{ab} p_i = G_{1i} p_1 + G_{2i} p_2 + \dots + G_{ji} p_j + \dots + w d_i(w)$$

or

$$(A.2) \quad t_i^{ab} p_i = \sum_j G_{ji} p_j + w d_i(w)$$

, where G_{ji} is the amount of intermediate good j used to produce the amount of output of final good i (t_i^{ab}) and d_i represents the amount of the primary factors necessary to produce the amount of output of final good i . Rearranging equation (A.2)

$$(A.2) \quad wd_i(w) = t_i^{ab} p_i - \sum_j G_{ji} p_j$$

and dividing by $t_i^{ab} p_i$, we have

$$(A.3) \quad V_i = 1 - \sum_j a_{ji}$$

$$, \text{ where } V_i = \frac{wd_i(w)}{t_i^{ab} p_i} \quad \text{and} \quad a_{ji} = \frac{G_{ji} p_j}{t_i^{ab} p_i}$$

Equation (A.3) gives us the value added per unit of output for the no-tariff situation.

In the tariff situation we have, in the place of equation (A.2),

$$(A.4) \quad t_i^{ab} p_i (1+s_i) = \sum_j G_{ji} p_j (1+s_j) + wd_i(w)$$

Rearranging and dividing by $t_i^{ab} p_i$, we have

$$(A.5) \quad V_i' = (1+s_i) - \sum_j a_{ji} (1+s_j)$$

, where V_i' is the value added in terms of tariff-ridden prices. The rate of effective protection, θ , is defined as

$$(A.6) \quad \theta_i = \frac{V_i' - V_i}{V_i}$$

$$= \frac{s_i - \sum_j a_{ji} s_j}{1 - \sum_j a_{ji}}$$

In our model the gross revenue of import tax on the final good i is

$$\begin{aligned} \text{(A.7)} \quad R_i &= (p_i^a - p_i^b) t_i^{ab} \\ &= t_i^{ab} p_i^b s_i \end{aligned}$$

, while the gross revenue of import tax on the intermediate good j is

$$\text{(A.8)} \quad Q_i = \sum_j G_{ji} p_j s_j$$

Thus

$$\text{(A.9)} \quad R_i - Q_i = t_i^{ab} p_i^b s_i - \sum_j G_{ji} p_j s_j$$

or

$$\text{(A.10)} \quad R_i - Q_i = (s_i - \sum_j a_{ji} s_j) t_i^{ab} p_i$$

The term in the parenthesis is identical to the numerator in the rate of effective protection equation (A.6). Consequently $(R_i - Q_i)$ depends on the rate of effective protection. (For more detail description of effective rate of protection, see Markusen and Melvin 1988, ch. 17 or Woodland 1982, ch. 10).

APPENDIX B

Special Cases

In this section we analyze the special case that intermediate goods are produced in only one country in the post-trade equilibrium. Furthermore we assume that trade in goods, including intermediate goods, is subject to trade barriers.

Special Case I. The intermediate goods are produced in country a only

In the trading equilibrium, the intermediate goods are assumed to be produced most cheaply in country a, but the final goods are produced in country b and exported to country a. In such a case it will have the property that

$$(B.1) \quad p^b T^{ab} = w^b T_d^{ab} + w^a T_e^{ab} + Q^b$$

where $Q^b = \sum_i \sum_j t_i^{ab} g_{ji} p_j^a s_j^b$. The reason is that the industries in country a will produce the final goods by importing the intermediate goods from country a, thereby paying a tariff of rate s_j .

It also will have the following condition:

$$\begin{aligned}
 (B.2) \quad p^a T^{ab} &\leq \sum_i c_i (w^a) t_i^{ab} \\
 &= \left[w^a \sum_i d_i (w^a) + w^a \sum_i e_i (w^a) \right] t_i^{ab} \\
 &\leq \left[w^a \sum_i d_i (w^b) + w^a \sum_i e_i^* (w^a) \right] t_i^{ab}, \\
 &\text{for all } i \in I^{ab}
 \end{aligned}$$

or

$$(B.3) \quad p^a T^{ab} \leq w^a T_d^{ab} + w^a T_e^{ab}$$

The relationship between equation (B.1) and equation (B.3) provide restriction on the pattern of factor content trade.

$$\begin{aligned}
 (B.4) \quad w^a T_d^{ab} + w^a T_e^{ab} &\geq p^a T^{ab} \\
 &= p^b T^{ab} + (p^a - p^b) T^{ab} \\
 &= w^b T_d^{ab} + w^a T_e^{ab} + Q^b + R^a
 \end{aligned}$$

where $R^a = (p^a - p^b) T^{ab} = \sum_i t_i^{ab} p_i^b s_i^a$. This equation reduces to

$$(B.5) \quad (w^a - w^b) T_d^{ab} \geq R^a + Q^b$$

This restriction tells us that a modified direct requirement test is relevant for this kind of test. In this case the definition of home-gross is the same as one of direct.

Special Case II The intermediate goods are produced in country b only.

The intermediate goods are assumed to be produced most cheaply in country b in the post-trade equilibrium, but the final goods are produced in country b and exported to country a . In this case it will have the property that

$$(B.6) \quad p^{bT^{ab}} = w^{bT_d^{ab}} + w^{bT_e^{ab}}$$

If country a produced the final goods, then country a might import the intermediate inputs required to produce the final goods from country b . This implies

$$\begin{aligned} (B.7) \quad p^{aT^{ab}} &\leq \sum_i c_i(w^a) t_i^{ab} \\ &= \left[w^a \sum_i d_i(w^a) + w^b \sum_i e_i(w^b) + \sum_i \sum_j g_{ji} p_j^{bs^a} \right] t_i^{ab} \\ &\leq \left[w^a \sum_i d_i(w^b) + w^b \sum_i e_i(w^b) + \sum_i \sum_j g_{ji} p_j^{bs^a} \right] t_i^{ab} \\ &\quad , \text{ for all } i \in I^{ab} \end{aligned}$$

or

$$(B.8) \quad p^{aT^{ab}} \leq w^a T_d^{ab} + w^b T_e^{ab} + Q^a$$

where $Q^a = \sum_i \sum_j t_i^{ab} g_{ji} p_j^{bs^a}$ stands for the total tariff revenue provided that the intermediate goods were imported.

Rearranging equation (B.8) and combining equation (B.6) yields the condition which the factor content pattern of bilateral trade must satisfy:

$$\begin{aligned}
 (B.9) \quad w^a T_d^{ab} + w^b T_e^{ab} + Q^a &\geq p^a T^{ab} \\
 &= p^b T^{ab} + (p^a - p^b) T^{ab} \\
 &= w^b T_d^{ab} + w^b T_e^{ab} + R^a
 \end{aligned}$$

or

$$(B.10) \quad (w^a - w^b) T_d^{ab} \geq R^a - Q^a$$

This restriction tells us that a modified direct requirement test holds only if the rate of effective protection is on average positive.

However, home-gross requirements test is also established. Consider the following equation:

$$(B.11) \quad \left[w^b \sum_i e_i^*(w^b) + \sum_i \sum_j \sum_l g_{jli} p_{jl}^{bs} s_j^a \right] t_i^{ab} \leq w^a \sum_i e_i(w^a) t_i^{ab}$$

which tell us that the cost of intermediate goods would be higher if they were all produced at home (here country a). Thus in place of equation (B.7) we have

$$\begin{aligned}
 (B.12) \quad p^a T^{ab} &\leq \sum_i c_i(w^a) t_i^{ab} \\
 &= \left[w^a \sum_i d_i(w^a) + w^a \sum_i e_i(w^a) \right] t_i^{ab} \\
 &\leq \left[w^a \sum_i d_i(w^b) + w^a \sum_i e_i(w^b) \right] t_i^{ab} \\
 &\quad , \text{ for all } i \in I^{ab}
 \end{aligned}$$

or

$$(B.13) \quad p^a T^{ab} \leq w^a T_d^{ab} + w^a T_e^{ab}$$

Rearranging equation (B.13) and substituting equation (B.6) we have

$$\begin{aligned} (B.14) \quad w^a T_d^{ab} + w^a T_e^{ab} &\geq p^a T^{ab} \\ &= p^b T^{ab} + (p^a - p^b) T^{ab} \\ &= w^b T_d^{ab} + w^b T_e^{ab} + R^a \end{aligned}$$

or

$$(B.15) \quad (w^a - w^b) (T_d^{ab} + T_e^{ab}) \geq R^a$$

This condition is related to home-gross requirements, consisting of both the direct factor inputs into final goods and the direct factor inputs into the intermediate goods used up to produce the final good. In this case the definition of home-gross is the same as one of gross.

APPENDIX C

Derivation of Equation (4.10)

We have supposed that country b produces final goods (I_δ) by purchasing some intermediate goods from domestic market and by importing the others from country a , thereby paying an ad valorem tariff of a rate s_α . In a trading equilibrium zero profit condition holds for all perfectly competitive industries implying unit cost pricing. If the number of goods in I_δ is n_δ , then the model gives rise to the following set of n_δ equations:

$$\begin{aligned}
 (C.1) \quad p_1^b &= d_1^b w^b + g_{1\beta}^b p_\beta^b + g_{1\gamma}^b p_\gamma^b + g_{1\alpha}^b p_\alpha^a + q_{1\alpha} \\
 &\vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \\
 p_i^b &= d_i^b w^b + g_{i\beta}^b p_\beta^b + g_{i\gamma}^b p_\gamma^b + g_{i\alpha}^b p_\alpha^a + q_{i\alpha} \\
 &\vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \\
 p_{n_\delta}^b &= d_{n_\delta}^b w^b + g_{n_\delta\beta}^b p_\beta^b + g_{n_\delta\gamma}^b p_\gamma^b + g_{n_\delta\alpha}^b p_\alpha^a + q_{n_\delta\alpha}
 \end{aligned}$$

where p_i^b is a scalar; d_i^b is a $1 \times m$ vector; w^b is a $m \times 1$ vector; $g_{i\beta}^b$, $g_{i\gamma}^b$, and $g_{i\alpha}^b$ are $1 \times n_\beta$, $1 \times n_\gamma$, and $1 \times n_\alpha$ vectors, respectively; p_β^b , p_γ^b , and p_α^b are $n_\beta \times 1$, $n_\gamma \times 1$, and $n_\alpha \times 1$ vectors, respectively; and $q_{i\alpha} = \sum_\alpha g_{i\alpha}^b s_\alpha^b$, according to equation (4.4), is a scalar.

We can collect terms and write in matrix form

$$(C.2) \quad \begin{bmatrix} p_1^b \\ \vdots \\ p_i^b \\ \vdots \\ p_{n_\delta}^b \end{bmatrix} = \begin{bmatrix} d_1^b & g_{1\beta}^b & g_{1\gamma}^b & g_{1\alpha}^b & q_{1\alpha} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ d_i^b & g_{i\beta}^b & g_{i\gamma}^b & g_{i\alpha}^b & q_{i\alpha} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ d_{n_\delta}^b & g_{n_\delta\beta}^b & g_{n_\delta\gamma}^b & g_{n_\delta\alpha}^b & q_{n_\delta\alpha} \end{bmatrix} \begin{bmatrix} w^b \\ p_\beta^b \\ p_\gamma^b \\ p_\alpha^a \\ 1 \end{bmatrix}$$

We write these expressions more compactly as

$$(C.3) \quad p_\delta^b = \begin{bmatrix} d^b & g_\beta^b & g_\gamma^b & g_\alpha^b & q_\alpha \end{bmatrix} \begin{bmatrix} w^b \\ p_\beta^b \\ p_\gamma^b \\ p_\alpha^a \\ 1 \end{bmatrix}$$

where p_δ^b is a $n_\delta \times 1$ column vector; d^b is a $n_\delta \times m$ matrix; g_β^b , g_γ^b , and g_α^b are, respectively, $n_\delta \times n_\beta$, $n_\delta \times n_\gamma$, and $n_\delta \times n_\alpha$ matrices; and q_α is a $n_\delta \times 1$ column vector.

Premultiplying equation (C.3) by a n_δ -element row vector T_δ gives

$$(C.4) \quad T_\delta p_\delta^b = \begin{bmatrix} T_\delta d^b & T_\delta g_\beta^b & T_\delta g_\gamma^b & T_\delta g_\alpha^b & T_\delta q_\alpha \end{bmatrix} \begin{bmatrix} w^b \\ p_\beta^b \\ p_\gamma^b \\ p_\alpha^a \\ 1 \end{bmatrix}$$

or

$$(C.5) \quad T_{\delta} p_{\delta}^b = \begin{bmatrix} D^b & G_{\beta}^b & G_{\gamma}^b & G_{\alpha}^b & Q_{\alpha} \end{bmatrix} \begin{bmatrix} w^b \\ p_{\beta}^b \\ p_{\gamma}^b \\ p_{\alpha}^a \\ 1 \end{bmatrix}$$

where D^b is a $1 \times m$ vector; G_{β}^b , G_{γ}^b , and G_{α}^b are, respectively, $1 \times n_{\beta}$, $1 \times n_{\gamma}$, and $1 \times n_{\alpha}$ vectors; and $Q_{\alpha} = \sum_{\alpha} G_{\alpha}^b p_{\alpha}^a s_{\alpha}^b$ is a scalar quantity. Thus this reduces to equation (4.10).

APPENDIX D

Derivation of Equation (4.11)

Conditions (4.6) and (4.8) implies ⁷⁷

$$(D.1) \quad p_i^a \leq c_i^a(w^j, p^j) \quad \text{for } i \in I_\delta, \quad j = a, b$$

Using equations (4.2), (4.3) and (4.9) we obtain

$$\begin{aligned} (D.2) \quad c_i^a(w^j, p^j) &= d_i^a w^a + g_{i\alpha}^a p_\alpha^a + g_{i\gamma}^a p_\gamma^a + g_{i\beta}^a p_\beta^b + q_{i\beta} \\ &= d_i^a w^a + g_{i\alpha}^a p_\alpha^a + g_{i\gamma}^a p_\gamma^a + g_{i\beta}^a p_\beta^a \\ &\leq d_i^b w^a + g_{i\alpha}^b p_\alpha^a + g_{i\gamma}^b p_\gamma^a + g_{i\beta}^b p_\beta^a, \\ &\quad \text{for } i \in I_\delta, \quad j = a, b \end{aligned}$$

We can rewrite these n_δ equations in the following matrix form

⁷⁷ In equation (D.1) $p_i^a < c_i^a$ for $i \in I_\beta$ and $p_i^a = c_i^a$ for $i \in I_\gamma$ where $I_\delta = I_\beta \cup I_\gamma$.

$$(D.3) \quad \begin{bmatrix} p_1^a \\ \vdots \\ p_i^a \\ \vdots \\ p_{n\delta}^a \end{bmatrix} = \begin{bmatrix} d_1^b & g_{1\alpha}^b & g_{1\gamma}^b & g_{1\beta}^b \\ \vdots & \vdots & \vdots & \vdots \\ d_i^b & g_{i\alpha}^b & g_{i\gamma}^b & g_{i\beta}^b \\ \vdots & \vdots & \vdots & \vdots \\ d_{n\delta}^b & g_{n\delta\alpha}^b & g_{n\delta\gamma}^b & g_{n\delta\beta}^b \end{bmatrix} \begin{bmatrix} w^a \\ p_\alpha^a \\ p_\gamma^a \\ p_\beta^a \end{bmatrix}$$

which can be expressed more compactly as

$$(D.4) \quad p_\delta^a = \begin{bmatrix} d^b & g_\alpha^b & g_\gamma^b & g_\beta^b \end{bmatrix} \begin{bmatrix} w^a \\ p_\alpha^a \\ p_\gamma^a \\ p_\beta^a \end{bmatrix}$$

Premultiplying equation (D.4) by a $1 \times n_\delta$ vector T_δ yields

$$(D.5) \quad T_\delta p_\delta^a = \begin{bmatrix} T_\delta d^b & T_\delta g_\alpha^b & T_\delta g_\gamma^b & T_\delta g_\beta^b \end{bmatrix} \begin{bmatrix} w^a \\ p_\alpha^a \\ p_\gamma^a \\ p_\beta^a \end{bmatrix}$$

or

$$(D.6) \quad T_\delta p_\delta^a = \begin{bmatrix} D^b & G_\alpha^b & G_\gamma^b & G_\beta^b \end{bmatrix} \begin{bmatrix} w^a \\ p_\alpha^a \\ p_\gamma^a \\ p_\beta^a \end{bmatrix}$$

which reduces to equation (4.11).

APPENDIX E

Derivation of Condition (4.28)

We decompose each set of intermediate goods into two sorts of goods, depending on whether goods are primary products or not, such that

$$I_{\Sigma} = (I_{\alpha\Sigma}, I_{\beta\Sigma}, I_{\gamma\Sigma}), \quad I_{\pi} = (I_{\alpha\pi}, I_{\beta\pi}, I_{\gamma\pi})$$

where $I_{\alpha\Sigma}$ denotes a subset of I_{Σ} that includes all non-primary goods in set I_{α} , $I_{\alpha\pi}$ is a subset of I_{π} that includes all primary goods in set I_{α} , etc. Then the import vector T_{δ} can be decomposed as

$$T_{\delta} = (T_{\delta\Sigma}, T_{\delta\pi})$$

where $T_{\delta\Sigma}$ and $T_{\delta\pi}$ give, respectively, the amounts of import of I_{δ} goods in set I_{Σ} and in set I_{π} . We also assume that natural resources are employed directly and only in the production of primary goods.

Under this assumption we can split and rewrite equation (4.15) for $T_{\delta\Sigma}$ goods as

$$(E.1) \quad p_{\delta\Sigma}^b = d_{\Sigma\mu}^b w_{\mu}^b + g_{\delta\Sigma\Sigma}^b p_{\delta\Sigma}^b + g_{\delta\Sigma\pi}^b p_{\delta\pi}^b + g_{\alpha\Sigma}^b p_{\alpha\Sigma}^a + q_{\alpha\Sigma}$$

By solving equation (E.1) for $p_{\delta\Sigma}^b$, we find

$$(E.2) \quad p_{\delta\Sigma}^b = \Lambda_{\Sigma\Sigma}^b d_{\Sigma\mu}^b w_{\mu}^b + \Lambda_{\Sigma\Sigma}^b g_{\delta\Sigma\pi}^b p_{\delta\pi}^b + \Lambda_{\Sigma\Sigma}^b g_{\alpha\Sigma}^b p_{\alpha\Sigma}^b + \Lambda_{\Sigma\Sigma}^b q_{\alpha\Sigma}$$

where $\Lambda_{\Sigma\Sigma}^b = (I - g_{\delta\Sigma\Sigma}^b)^{-1}$.

By the same token, we also can split and rewrite equation (4.21) for $T_{\delta\Sigma}$ goods as

$$(E.3) \quad p_{\delta\Sigma}^a = d_{\Sigma\mu}^b w_{\mu}^a + g_{\alpha\Sigma}^b p_{\alpha\Sigma}^a + g_{\delta\Sigma\Sigma}^b p_{\delta\Sigma}^a + g_{\delta\Sigma\pi}^b p_{\delta\pi}^a$$

Solving equation (E.3) for $p_{\delta\Sigma}^a$ gives

$$(E.4) \quad p_{\delta\Sigma}^a = \Lambda_{\Sigma\Sigma}^b d_{\Sigma\mu}^b w_{\mu}^a + \Lambda_{\Sigma\Sigma}^b g_{\alpha\Sigma}^b p_{\alpha\Sigma}^a + \Lambda_{\Sigma\Sigma}^b g_{\delta\Sigma\pi}^b p_{\delta\pi}^a$$

Premultiplying equations (E.2) and (E.4) by a vector $T_{\delta\Sigma}$, respectively, we obtain

$$(E.5) \quad T_{\delta\Sigma} p_{\delta\Sigma}^b = T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b d_{\Sigma\mu}^b w_{\mu}^b + T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b g_{\alpha\Sigma\pi}^b p_{\delta\pi}^b \\ + T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b g_{\alpha\Sigma}^b p_{\alpha\Sigma}^a + T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b q_{\alpha\Sigma}$$

and

$$(E.6) \quad T_{\delta\Sigma} p_{\delta\Sigma}^a = T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b d_{\Sigma\mu}^b w_{\mu}^a + T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b g_{\alpha\Sigma}^b p_{\alpha\Sigma}^a + T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b g_{\delta\Sigma\pi}^b p_{\delta\pi}^a$$

Rearranging equation (E.6) and equating with equation (E.5), we have

$$(E.7) \quad T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b d_{\Sigma\mu}^b (w_{\mu}^a - w_{\mu}^b) + T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b g_{\delta\Sigma\pi}^b (p_{\delta\pi}^a - p_{\delta\pi}^b) = Q_{\alpha\Sigma}^* + R_{\delta\Sigma}$$

where $Q_{\alpha\Sigma}^* = T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b q_{\alpha\Sigma}$; and $R_{\delta\Sigma} = T_{\delta\Sigma} (p_{\delta\Sigma}^a - p_{\delta\Sigma}^b)$.

For $T_{\delta\pi}$ goods we have

$$p_i^a \geq p_i^b \quad \text{for } i \in I_{\delta\pi}$$

and thus

$$T_{\delta\pi} p_{\delta\pi}^a \geq T_{\delta\pi} p_{\delta\pi}^b$$

$$(E.8) \quad T_{\delta\pi} (p_{\delta\pi}^a - p_{\delta\pi}^b) \geq 0$$

Thus we combine equation (E.7) with equation (E.8) to yield condition (4.28)

$$(4.28) \quad T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b d_{\Sigma\mu}^b (w_\mu^a - w_\mu^b) + T_{\delta\Sigma} \Lambda_{\Sigma\Sigma}^b g_{\delta\Sigma\pi}^b (p_{\delta\pi}^a - p_{\delta\pi}^b) \\ + T_{\delta\pi} (p_{\delta\pi}^a - p_{\delta\pi}^b) \geq Q_{\alpha\Sigma}^* + R_{\delta\Sigma}$$

If we express $T_{\delta\pi}$ goods in the same manner as in $T_{\delta\pi}$ goods, then we have the same amount of tariff revenues in both equations (4.25) and (4.28). We also can split and rewrite equation (4.15) for $T_{\delta\pi}$ goods as

$$(E.9) \quad p_{\delta\pi}^b = d_{\pi\mu}^b w_\mu^b + d_{\pi\nu}^b w_\nu^b + g_{\delta\pi\Sigma}^b p_{\delta\Sigma}^b + g_{\delta\pi\pi}^b p_{\delta\pi}^b + g_{\alpha\pi}^b p_{\alpha\pi}^a + q_{\alpha\pi}$$

solving for $p_{\delta\pi}^b$ and multiplying by $T_{\delta\pi}$ gives

$$(E.10) \quad T_{\delta\pi} p_{\delta\pi}^b = T_{\delta\pi} \Lambda_{\pi\pi}^b d_{\pi\mu}^b w_\mu^b + T_{\delta\pi} \Lambda_{\pi\pi}^b d_{\pi\nu}^b w_\nu^b + T_{\delta\pi} \Lambda_{\pi\pi}^b g_{\delta\pi\Sigma}^b p_{\delta\Sigma}^b \\ + T_{\delta\pi} \Lambda_{\pi\pi}^b g_{\alpha\pi}^b p_{\alpha\pi}^a + T_{\delta\pi} \Lambda_{\pi\pi}^b q_{\alpha\pi}$$

where $\Lambda_{\pi\pi}^b = \left(I - g_{\delta\pi\pi}^b \right)^{-1}$.

By the same token, we reexpress equation (4.21) for

$T_{\delta\pi}$ goods as

$$(E.11) \quad p_{\delta\pi}^a = d_{\pi\mu}^b w_{\mu}^a + d_{\pi\nu}^b w_{\nu}^a + g_{\alpha\pi}^b p_{\alpha\pi}^a + g_{\delta\pi\Sigma}^b p_{\delta\Sigma}^a + g_{\alpha\pi\pi}^b p_{\delta\pi}^a$$

solving for $p_{\delta\pi}^a$ and multiplying by $T_{\delta\pi}$ gives

$$(E.12) \quad T_{\delta\pi} p_{\delta\pi}^a = T_{\delta\pi} \Lambda_{\pi\pi}^b d_{\pi\mu}^b w_{\mu}^a + T_{\delta\pi} \Lambda_{\pi\pi}^b d_{\pi\nu}^b w_{\nu}^a + T_{\delta\pi} \Lambda_{\pi\pi}^b g_{\alpha\pi}^b p_{\alpha\pi}^a \\ + T_{\delta\pi} \Lambda_{\pi\pi}^b g_{\delta\pi\Sigma}^b p_{\delta\Sigma}^a$$

From equations (E.10) and (E.12) we derive the following relationship

$$(E.13) \quad T_{\delta\pi} \Lambda_{\pi\pi}^b d_{\pi\mu}^b (w_{\mu}^a - w_{\mu}^b) + T_{\delta\pi} \Lambda_{\pi\pi}^b d_{\pi\nu}^b (w_{\nu}^a - w_{\nu}^b) \\ + T_{\delta\pi} \Lambda_{\pi\pi}^b g_{\delta\pi\Sigma}^b (p_{\delta\Sigma}^a - p_{\delta\Sigma}^b) = Q_{\alpha\pi}^* + R_{\delta\pi}$$

where $Q_{\alpha\pi}^* = T_{\delta\pi} \Lambda_{\pi\pi}^b q_{\alpha\pi}$ and $R_{\delta\pi} = \Pi_{\delta\pi} (p_{\delta\pi}^a - p_{\delta\pi}^b)$.

Thus combining equation (E.7) with equation (E.13) yields another form of condition (4.28) in which the sum of tariff revenues is the same as that in condition (4.25):

$$(E.14) \quad \left(Q_{\alpha\Sigma}^* + Q_{\alpha\pi}^* \right) + \left(R_{\delta\Sigma} + R_{\delta\pi} \right) = Q_{\alpha}^* + R_{\delta}$$

Appendix F

Mathematical Derivation of the Input Requirements Matrix

This subsection shows the matrix algebra underlying the derivation of the input requirements from the 1980 input-output tables for the U.S. We use a commodity by industry input-output model to account for the possibility that an industry produces more than one commodity.⁷⁸ A commodity by industry input-output format can be summarized schematically as in Table F.1.⁷⁹

. Table F.1

A Schematic Arrangement of Input-Output Data

Commodities		Industries	Final Demand	Total Output
Commodities		U	F*	Q
Industries	V			X
Value Added		W		
Total Output	Q'	X'		

⁷⁸ The general input-output model is laid out in Miller and Blair (1985) among others.

⁷⁹ For more a detailed input-output structure for the U.S., see Survey of Current Business, May 1984.

Let us adopt the following notation for m commodities and n industries in the economy.

$V = [V_{ij}]$ is the $n \times m$ "make" matrix with the element V_{ij} representing the amount of commodity j produced by industry i .

$U = [U_{ij}]$ is the $m \times n$ "use" matrix with the element U_{ij} representing the amount of commodity i used by industry j .

$F = [F_{ij}]$ is the $m \times K$ matrix with the element F_{ij} representing the amount of commodity i delivered to final demand j .

$D = [D_i]$ is the $m \times 1$ vector of commodity i deliveries to personal consumption expenditures in final demand categories.

$I = [I_i]$ is the $m \times 1$ vector of commodity i deliveries to gross private domestic investment in final demand categories.

$E = [E_i]$ is the $m \times 1$ vector of commodity i deliveries to domestic exports in final demand categories.

$M = [M_i]$ is the $m \times 1$ vector of commodity i deliveries to imports in final demand categories.

$G = [G_i]$ is the $m \times 1$ vector of commodity i deliveries to government purchases in final demand categories.

$Q = [Q_i]$ is the $m \times 1$ vector of commodity total outputs.

$X = [X_j]$ is the $n \times 1$ vector of industry total outputs.

$W = [W_j]$ is the $1 \times n$ vector of industry value-added inputs.

A circumflex ($\wedge$) over the symbol for a vector indicates a square matrix in which the elements of the vector appear on the main diagonal and zeros are entered elsewhere.

i denotes a unit vector containing only 1's.

In terms of Table F.1, input-output analysis rests on the following relationships, three of which are basic accounting identities and the fourth is based on assumptions relating to the technical conditions of production.

The first relationship is an industry output identity:

$$(F.1) \quad X = V i$$

that is to say each industry's gross output is equal to the sum of its outputs of each commodity.

The second and third relationships are commodity output identities:

$$(F.2) \quad Q = U i + F$$

which states that the domestic production of each commodity is absorbed either as intermediate product or as net final product, and

$$(F.3) \quad Q = V' i$$

that is to say, the output of each commodity is equal to the sum of the amounts made in each of the industries.

The fourth relationship is the commodity by industry

direct requirement:⁸⁰

$$(F.4) \quad U = B\hat{X}$$

where B is a matrix of coefficients of dimensions, commodity by industry. Equation (F.4) states that intermediate inputs of commodities are proportional to the industry outputs into which they enter.

From this point, we can calculate a total requirements matrix based on an assumption of either a commodity-based technology, which implies that a commodity has the same input requirements regardless of which industry produces it, or an industry-based technology, which implies that the input requirements of commodities depends upon the industry in which they are produced. We assume a commodity-based technology which is considered to be more appropriate to the assumption underlying the theoretical model. Thus the final relationship is the commodity-based technology assumption:⁸¹

⁸⁰ Let B denote a commodity by industry matrix in which the element $B_{ij} = \frac{U_{ij}}{\hat{x}_j}$ show the dollars' worth of commodity i required to produce one dollar's worth of industry j 's output. In matrix term it can be written as $B = U (\hat{X})^{-1}$.

⁸¹ By dividing an element of make matrix by the total output (in dollars) of industry i we determine the industry output proportion denoted by $c_{ij} = \frac{V_{ij}}{\hat{x}_i}$ which shows industry i 's output (in dollars) of commodity j as a proportion of its total output. In matrix terms, $C = V'(\hat{X})^{-1}$ where C is of dimension m commodities and n industries.

$$(F.5) \quad V' = CX$$

where C is a matrix of coefficients of dimensions commodity-by-industry in which a column gives an industry's output (in dollars) of different commodities as a proportion of its total output, and V' is the transpose of V . Equation (F.5) states that each industry makes commodities in its own fixed proportions.⁸²

The model thus involves two constants: B and C , and five variables: U , V , F , Q , and X . The solution is derived as follows.

From equations (F.2), (F.3), (F.4), and (F.5) we can write⁸³

$$\begin{aligned} Q &= U i + F \\ &= BX + F \\ &= BC^{-1} Q + F \\ (F.6) \quad &= (I - BC^{-1})^{-1} F \end{aligned}$$

where I denotes the unit matrix and $(I - BC^{-1})^{-1}$ is the commodity-by-commodity total requirements matrix in which the ij th element gives the dollars' worth of commodity i

⁸² The U.S. input-output tables have alternatively adopted the industry-based technology assumption. The corresponding relationship is $V = ZX$ where Z is a matrix of coefficients of dimensions industry by commodity. It states that commodities come in their own fixed proportions from the various industries.

⁸³ It will be noticed that equation (F.6) involves the matrix inverse, C^{-1} . Since a matrix can only be converted if it is square, the assumption of a commodity technology can only be used if the number of industries is equal to the number of commodities as in the U.S. input-output table.

required to deliver one dollar's worth of commodity j to final demand.

APPENDIX G

Notes on Data and Adjustment Methodology

This appendix provides a full description of data sources and adjustment methodology used in this paper.

G.1 Basic Tables

Table G.1

U.S. Dollar Exchange Rates in National Currencies, 1980

Country	Exchange Rate [*]
CAN	1.17
UK	0.43
JAP	226.70

* yearly averages of exchange rates as published by the IMF.

Table G.2

Input-Output Sector Aggregation Codes

26 - Sector Aggregation	85-Sector Aggregation Industry Numbers *	Capital Stock Industry Numbers **	Employment Industry Numbers ***	Related SIC Codes *
1. Agriculture, Forestry, and Fishing	1 - 4	4, 5	4, 5	01, 02, and 07 - 09
2. Mining and Quarrying	5 - 7, 9, 10	6, 7, 9	6, 7, 9	10 - 12, 14
3. Oil and Gas Extraction	8	8	8	13
4. Food and Beverages	14	22	22	20
5. Tobacco	15	23	23	21
6. Textile Products and Apparel	16 - 19	24, 25	24, 25	22, 23
7. Wood Products	20, 21	11	11	24
8. Furniture	22, 23	12	12	25
9. Paper Products	24, 25	26	26	26
10. Printing and Publishing	26	27	27	27
11. Chemical Products	27 - 30	28	28	28
12. Petroleum and Coal Products	31	29	29	29
13. Rubber and Plastics	32	30	30	30
14. Leather Products	33, 34	31	31	31
15. Stone, Clay, and Glass Products	35, 36	13	13	32
16. Primary and Fabricated Metals	37 - 42	14, 15	14, 15	33, 34

17. Machinery	43 - 52	16	16	35
18. Electrical Products	53 - 58	17	17	36
19. Transportation Equipment	59 - 61, 13	18, 19	18, 19	37
20. Miscellaneous Products	62 - 64	20, 21	20, 21	38, 39
21. Construction	11, 12	10	10	15 - 17
22. Transportation and Warehousing	65	32 - 38	32 - 38	40 - 42, 44 - 47
23. Communications and Utilities	66 - 68, 78, 79	39 - 43	39 - 41	43, 48 49
24. Wholesale & Retail Trade	69	44, 45	42, 43	50 - 57, 59
25. Finance, Insurance, & Real Estate	70, 71	46 - 54	44 - 50	60 - 67
26. Community, Social, & Personal Services	72 - 77	55 - 66	51 - 62	58, 70 - 89

* Detailed sectoral definitions are provided in Table G.3. Mapping of the input-output parameters to their respective SIC codes are given in Appendix B of the Survey of Current Business, May 1984. U.S. Commodities are matched one-to-one with industries. Here 26-Sectors are defined in terms of the two-digit SIC codes (1977 edition).

** The capital stock data is directly supplied by BEA. Descriptions of industries are provided in Table G.11.

*** Employment by I/O classification is derived from the National Income and Product Accounts of the United States, 1929-82. Descriptions of industries are provided in Table G.13.

Table G.3

Industry Classification of the Input-Output Tables, 1980

Industry Number	Title
1	Livestock and livestock products
2	Other agricultural products
3	Forestry and fishery products
4	Agricultural, forestry, and fishery products
5	Iron and ferroalloy ores mining
6	Nonferrous metal ores mining
7	Coal mining
8	Crude petroleum and natural gas
9	Stone and clay mining and quarrying
10	Chemical and fertilizer mineral mining
11	New construction
12	Maintenance and repair construction
13	Ordnance and accessories
14	Food and kindred products
15	Tobacco manufactures
16	Broad and narrow fabrics, yarn and thread mill's
17	Miscellaneous textile goods and floor coverings
18	Apparel
19	Miscellaneous fabricated textile products
20	Lumber and wood products, except containers
21	Wood containers
22	Household furniture
23	Other furniture and fixtures
24	Paper and allied products, except containers
25	Paperboard containers and boxes
26	Printing and publishing
27	Chemicals and selected chemical products
28	Plastics and synthetic materials

Industry Number	Title
<hr/>	
29	Drugs, cleaning and toilet preparations
30	Paints and allied products
31	Petroleum refining and related industries
32	Rubber and miscellaneous plastics products
33	Leather tanning and finishing
34	Footwear and other leather products
35	Glass and glass products
36	Stone and clay products
37	Primary iron and steel manufacturing
38	Primary nonferrous metals manufacturing
39	Metal containers
40	Heating, plumbing, and fabricated structural metal products
41	Screw machine products and stampings
42	Other fabricated metal products
43	Engines and turbines
44	Farm and garden machinery
45	Construction and mining machinery
46	Materials handling machinery and equipment
47	Metalworking machinery and equipment
48	Special industry machinery and equipment
49	General industrial machinery and equipment
50	Miscellaneous machinery, except electrical
51	Office, computing, and accounting machines
52	Service industry machines
53	Electric industrial equipment and apparatus
54	Household appliances
55	Electric lighting and wiring equipment
56	Radio, TV, and communication equipment
57	Electronic components and accessories
58	Miscellaneous electrical machinery and supplies

Industry Number	Title
<hr/>	
59	Motor vehicles and equipment
60	Aircraft and parts
61	Other transportation equipment
62	Scientific and controlling instruments
63	Optical, ophthalmic, and photographic equipment
64	Miscellaneous manufacturing
65	Transportation and warehousing
66	Communications, except radio and TV
67	Radio and TV broadcasting
68	Electric, gas, water, and sanitary services
69	Wholesale and retail trade
70	Finance and insurance
71	Real estate and rental
72	Hotels; personal and repair services (except auto)
73	Business services
74	Eating and drinking places
75	Automobile repair and services
76	Amusements
77	Health, educational, and social services and nonprofit organizations
78	Federal Government enterprises
79	State and local government enterprises

Source: Appendix B, Survey of Current Business 65,
no. 11 (November 1988): 21-25.

Table G.4

Correspondence of Occupational Classification among Countries

Group	US	CAN	UK	JAP
1	-Professional specialty occupations/ Technicians & related support occupations (16, 17, 18, 19, 20's, 30's) Plus: Health service occupation (523)	-Occupations in natural sciences, engineering & mathematics (21) -Occupations in social sciences & related fields (23) -Occupations in religion (25) -Teaching & related occupations (27) -Occupations in medicine & health (31) -Artistic, literary, recreational & related occupations (33)	-Professional & related in education, welfare & health (Group III) -Literary, artistic & sports (Group IV) -Professional & related in science, engineering, technology & similar fields (Group V)	-Occupations belonged under this category
2	-Executive, administrative, & managerial occupations (11-14)	-Managerial, administrative & related occupations (11)	-Professional & related supporting management & administration (Group II) -Managerial (Group VI)	-Occupations belonged under this category

Group	US	CAN	UK	JAP
3	-Sales occupations (40-44)	-Sales occupations (51)	-Selling (Group VIII)	-Occupations belonged under this category
4	-Administrative support occupations, including clerical (45-47)	-Clerical & related occupations (41)	-Clerical & related (Group VII)	-Occupations belonged under this category
5	-Farming, forestry, & fishing occupations (55-58) Plus: Laborers, except construction (8769)	The sum of: -Farming, horticultural & animal husbandry occupations (71) -Fishing, trapping, & related occupations (73) -Forestry & logging occupations (75)	-Farming, fishing & related (Group XI)	-Occupations belonged under this category
6	-Service occupations (50, 51, 52) Less: Health service occupations (523)	-Service occupations (61)	-Security & protective service (Group IX) -Catering, cleaning, hairdressing & other personal service (Group X)	-Occupations belonged under this category
7**	-Other occupations (60's, 70's, 80's, except 8769)	-Other occupations (77, 80's, 90's)	-Other occupations (Group XII - XVIII)	-Occupations belonged under this category

- * Applicable only for the Farming, Forestry and Fishing Industries
- ** Total (all occupations) Less: subtotal of 1 to 6

Source: U.S. - Standard Occupational Classification Manual 1980, U.S. Department of Commerce Number in Parentheses are the SOCM definitions.

Canada - Standard Occupational Classification 1980, Statistics Canada. Number in Parentheses are the SOC definitions.

U.K. - List of Key Occupations (KOS), Appendix 2, New Earnings Survey 1980, Department of Employment. Number in Parentheses are the KOS groups.

Japan - Monthly Contract Cash Earnings of Regular Workers by Occupation (1980), Table 299, Japan Statistical Yearbook 1982.

Table G.5

26 - Sector Use Matrix: Commodity by Industry, 1980
 (100,000 Dollars--Producer's Price)

(U)

Industry> Commodity	1	2	3	4	5	6
1	459134	88	26	784653	29200	21611
2	2270	50837	0	1562	88	544
3	0	0	39455	0	0	0
4	138861	23	49	463374	79	240
5	0	0	0	0	37877	0
6	2385	564	100	727	16	371889
7	2361	1364	0	1091	59	200
8	0	0	0	0	0	0
9	3730	515	63	75995	3028	9422
10	366	150	133	12306	1530	1035
11	100207	7609	5803	29713	410	110222
12	81645	15921	6157	15929	833	9199
13	8170	3776	241	22811	2947	10785
14	344	0	20	14	0	3376
15	1086	1571	220	39903	22	1455
16	3983	11723	9728	88203	910	820
17	13600	27062	9587	4085	118	6040
18	4982	2257	3417	204	8	629
19	5043	1293	66	95	14	58
20	296	472	503	716	35	8104
21	20563	2770	48211	11569	230	4363
22	29070	4578	2624	61042	1180	11417
23	29585	20880	12062	43416	1099	26184
24	92453	15356	6006	151566	2029	50901
25	127126	12885	65192	18822	1695	11513
26	41458	17921	16184	86472	9283	36646

7	8	9	10	11	12	13
44718	2	252	2	4780	5	5
79	55	4558	37	32905	2625	512
0	0	0	0	37170	1262597	1228
34	427	3199	182	14798	405	107
0	0	0	0	0	0	0
731	13148	9043	1154	1546	186	14751
142868	20856	36021	15	907	288	1439
0	1068	21	0	0	0	0
1481	2939	183508	117666	29333	5956	11831
237	356	688	65851	3158	158	400
8521	3806	38050	14812	451576	47033	124826
9432	1963	25790	5695	51430	179709	8569
2691	10599	11508	4153	23159	1667	21327
122	573	11	66	83	53	80
2611	1589	1157	213	8502	2465	4240
15127	28973	7032	2023	45180	7562	10241
3781	1379	5071	3801	13446	2251	4541
649	319	100	164	490	91	720
678	20	78	114	86	1385	288
306	298	515	8703	2096	415	752
2598	1384	6652	2364	10942	10044	2709
10743	4660	28751	18367	51868	63916	12254
8329	4583	31286	25718	77160	42786	13039
25550	13334	43664	30770	76193	32769	17195
4366	4944	5712	17548	23977	10893	6755
11136	13443	21236	64222	113557	27547	16939

14	15	16	17	18	19	20
0	32	27	13	27	24	290
34	26765	114913	425	637	582	581
0	0	522	0	0	0	0
5211	229	223	215	152	98	696
0	0	0	0	0	0	0
5513	1701	870	1370	1101	24353	8929
432	3432	6092	2456	2088	10527	5670
0	0	24	28	3716	4216	34
1596	10758	9216	7977	11883	2568	17364
187	537	3087	2405	4063	1819	1570
3600	16898	59447	7919	26496	12838	30296
431	13061	29658	13546	7809	11419	6339
4369	2027	14987	27142	41446	47462	19080
18157	45	55	18	21	58	1075
70	52757	13319	10200	16277	16797	4412
968	8676	781811	275723	173305	303129	51889
335	5046	58214	263458	19464	87498	5648
11	808	14881	86291	223976	80422	24061
1	1055	948	7347	1058	414084	198
901	1082	3424	5171	8169	12745	27018
308	6071	28233	7452	6476	5979	2583
1326	32422	71637	23665	21559	26435	11901
1822	29873	95915	30173	28122	26651	12137
3807	17295	137894	104124	82767	86263	33846
1499	6957	24335	22546	35525	20265	11270
4419	16969	65456	72593	72739	78183	39781

21	22	23	24	25	26
4933	109	8490	10194	20641	42807
26263	51	106041	0	81	236
0	1701	278779	0	0	0
125	913	8360	4720	95	399783
0	0	0	0	0	0
17831	2448	1487	2049	962	23627
204828	232	758	8408	41	2691
7392	0	0	0	0	56
10983	1490	2705	4384	6536	37422
141	3539	6322	23541	27222	77198
48214	1906	10469	1911	3555	110432
81465	215937	194251	132167	18173	103323
34349	12645	2690	15627	3763	40726
31	42	174	1300	143	1169
222942	921	1304	847	339	17180
434746	10252	5819	6287	1577	41700
78346	9591	19557	11529	1017	40378
108338	4629	37242	3546	2839	38780
1749	37869	5148	5249	798	66484
20079	2328	6522	11876	6126	75923
3026	63767	161675	36197	272758	85900
77554	250200	59675	121168	18147	105755
40883	31477	527951	238061	135436	273275
304461	57996	38931	103404	19967	242401
40166	40590	58780	313394	733273	373803
320033	113395	112873	723006	267790	739552

Source: Bureau of Economic Analysis of the U.S.
Department of Commerce.

Table G.6

26 - Sector Make Matrix: Industry by Commodity, 1980

(100,000 Dollars--Producer's Price)

(V)

Commodity> Industry	1	2	3	4	5	6
1	1746248	0	0	59808	0	0
2	0	420211	25	2	0	0
3	0	36	1051125	0	0	0
4	78	0	0	2502909	0	154
5	0	0	0	0	166980	0
6	0	0	0	55	0	998603
7	0	0	0	2	0	53
8	0	0	0	0	0	770
9	0	0	0	1	409	2121
10	0	0	0	0	27	379
11	0	506	623	7130	0	4607
12	0	349	0	0	0	30
13	0	28	0	390	0	2624
14	0	0	0	16	0	809
15	0	2496	0	0	0	426
16	0	94	0	111	0	378
17	0	0	0	111	0	282
18	0	0	0	0	0	568
19	0	0	0	0	0	568
20	0	0	0	62	0	1201
21	0	0	0	0	0	0
22	575	0	0	0	0	0
23	0	0	2085	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0

7	8	9	10	11	12	13
1360	0	0	0	0	0	0
0	0	0	0	13247	725	0
0	0	0	0	1010	66372	0
42	15	619	114	7574	6	729
0	0	33	0	0	0	0
387	761	1696	455	14637	54	1528
454266	817	829	1	811	89	622
905	210862	108	38	76	0	592
1043	8	692019	3512	3699	75	5962
93	123	4480	428124	72	0	254
132	9	1069	551	1509059	17847	5037
10	0	136	0	138420	1818481	215
148	550	1358	371	8240	89	440287
257	3	38	57	34	6	298
389	60	646	24	2730	1273	1241
1187	1024	2549	2571	9018	45	3530
457	938	434	630	3194	15	1950
156	947	483	222	1422	6	1658
144	1077	568	100	294	145	1013
337	918	1157	1163	8032	18	3093
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	4162	627	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

14	15	16	17	18	19	20
0	0	0	0	0	0	0
0	2925	0	0	0	0	0
0	0	0	277	0	0	0
0	0	655	274	61	0	213
0	0	248	0	0	0	4
396	731	227	542	64	99	1685
3	148	1825	198	158	257	286
48	400	1399	868	788	362	947
26	385	2837	1752	1636	92	3138
46	0	1033	587	152	0	1013
36	1930	2135	2286	2205	166	5984
11	1023	647	137	0	0	20
423	1450	2681	3011	952	1532	1528
94611	58	173	77	0	43	254
2	436674	1312	1146	1199	453	845
20	2685	2360592	24129	9348	10173	3969
8	582	28714	1677242	30055	19041	7690
59	1045	15174	23075	1242789	11777	7576
0	796	22572	28505	17253	1907817	3271
233	1119	3761	5368	9098	2538	592960
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	271	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

21	22	23	24	25	26
0	247	0	0	0	1320
0	0	0	0	0	0
0	0	41367	0	0	0
0	0	0	0	0	15
0	0	0	0	0	0
0	0	0	0	0	13
0	0	0	0	0	1
0	0	0	0	0	38
0	0	0	0	0	445
0	0	0	0	0	263084
0	0	0	0	0	17
0	0	0	0	0	0
0	0	0	0	0	14
0	0	0	0	0	4
0	0	0	0	0	15
0	0	735	0	0	57
0	0	0	0	0	98
0	0	0	0	0	31
0	0	0	0	0	0
0	0	0	0	0	8099
3676687	0	0	0	0	0
0	1833467	18179	0	0	25
0	45547	2921780	26832	31163	149707
0	0	0	5603517	0	0
0	0	0	0	5698169	10178
0	0	0	0	14090	7442795

Source: Bureau of Economic Analysis of the U.S.
Department of Commerce.

Table G.7

Total Output Vector: 26 - Sector Aggregation
 (Millions of Dollars)
 (X)

Industry Number	Total Industry Outputs
1	180898.3
2	43713.5
3	116018.7
4	251345.8
5	16726.5
6	102193.3
7	46036.6
8	21820.1
9	71916
10	69947.1
11	156132.9
12	195948.4
13	46567.6
14	9673.8
15	45093.1
16	243221.9
17	177144.1
18	130698.8
19	198412.3
20	63915.7
21	367668.7
22	185224.6
23	318217.4
24	560351.7
25	570834.7
26	745688.5

Source: U.S. National Input-Output Tables: 1980.

Table G.8
Final Demands
(Millions of Dollars)

Industry Number	M	D + I + G
1	-3514.4	11115.9
2	-3188.9	2634.2
3	-60439.4	2061.5
4	-12449.9	153359.6
5	-317.7	10973.1
6	-10742.3	56341.1
7	-3692.2	999.2
8	-1229.5	20861.2
9	-5437.2	10891.5
10	-577.2	19412.5
11	-10719.8	35804.7
12	-20453.5	80657.2
13	-3347.9	8448.4
14	-3927.6	10290.5
15	-2689.3	3823.9
16	-20089.7	17570.6
17	-15196.4	89337.7
18	-17091.4	68436.5
19	-31605.8	143187.4
20	-11717.4	46093.6
21	0	287144.8
22	-14	60792.5
23	-4828.7	120221.3
24	7137.2	351326.6
25	-679	368779.2
26	-135.8	471794.7

Source: U.S. National Input-Output Tables, 1980.

Table G.9

Direct Input Requirements : Commodity by Commodity

 $(\tilde{g}^b)$

Commodity> Commodity	1	2	3	4	5	6
1	0.2464	0.0013	0.000001	0.0715	0	0.0013
2	0.0001	0.1103	0	0	0	0.0012
3	0	0	0	0.000040	0	0.000047
4	0.2983	0.0005	0	0.1762	0.000000	0.0002
5	0.1711	0.0004	0	0.0005	0.222	0.000090
6	0.0194	0.0001	0	0.000073	0.000000	0.3349
7	0.0906	0	0	0.000041	0.000000	0.0013
8	0	0	0	0.0019	0.000000	0.0575
9	0.000050	0.0058	0	0.0043	0	0.0107
10	0	0	0	0	0	0.0002
11	0.0015	0.0202	0.0154	0.0084	0.000000	0
12	0	0	0.6238	0	0.000000	0.000099
13	0	0.0002	0.0022	0	0.000000	0.0288
14	0	0.0002	0	0.0384	0.000000	0.0384
15	0	0.0568	0	0.0004	0.000000	0.0032
16	0	0.0446	0.0001	0.000070	0.000000	0.0001
17	0	0	0	0.000090	0.000000	0.0004
18	0	0	0	0.000091	0.000000	0.0004
19	0.000000	0	0	0.000037	0.000000	0.0106
20	0.0002	0.0002	0	0.0003	0.000000	0.0114
21	0.0013	0.0071	0	0.000033	0	0.0048
22	0	0	0	0.0005	2.0E-12	0.0013
23	0.0025	0.0357	0.0937	0.000080	0	0.0003
24	0.0018	0	0	0.0009	0	0.0004
25	0.0036	0.000014	0	0	0	0.0002
26	0.0057	0.000031	0	0.0537	0	0.0032

7	8	9	10	11	12	13
0.0011	0.000000	0.0011	0.000032	0.0557	0.0454	0.0043
0.0029	0.000000	0.0004	0.0003	0.0078	0.0336	0.0078
0	0.000000	0	0.000043	0.0031	0	0.0001
0.0004	0	0.0288	0.0047	0.0103	0.0059	0.0086
0.0003	0.000000	0.0177	0.009	0.0024	0.0049	0.0173
0	0	0.0076	0.0008	0.0948	0.0077	0.0093
0.2893	0	0.0024	0.0005	0.0162	0.0189	0.0057
0.0921	0.0048	0.0127	0.0015	0.0153	0.0084	0.0467
0.0476	0.000021	0.2434	0.0002	0.0464	0.0339	0.0146
0	0	0.2653	0.1455	0.0241	0.0042	0.0059
0.0004	0	0.0175	0.0019	0.2781	0.0305	0.0139
0.000099	0.000000	0.0016	0	0.0028	0.0867	0
0.0026	0	0.0234	0.0006	0.2571	0.0171	0.0442
0.0029	0	0.0114	0.0013	0.025	0.003	0.0319
0.007	0	0.0225	0.0011	0.0335	0.0273	0.0039
0.0021	0	0.0028	0.001	0.0214	0.0112	0.0053
0.001	0	0.0038	0.0012	0.0025	0.0068	0.0135
0.0012	0.0026	0.0079	0.0028	0.0173	0.005	0.0283
0.0045	0.0018	0.0008	0.0007	0.005	0.0047	0.0203
0.0074	0	0.0227	0.0017	0.0366	0.0078	0.0253
0.0557	0.002	0.003	0.000038	0.0131	0.0222	0.0093
0.0001	0.000000	0.0008	0.0019	0.001	0.1171	0.0069
0.0002	0	0.0005	0.0015	0.0023	0.0626	0.0005
0.0015	0	0.0079	0.0043	0.0003	0.0239	0.0028
0.000006	0	0.0011	0.0048	0.0006	0.0032	0.0006
0.0004	0.000007	0.005	0.0104	0.0148	0.0139	0.0055

14	15	16	17	18	19	20
0.0002	0.000068	0.001	0.0075	0.0028	0.0028	0.0001
0	0.0025	0.0247	0.0589	0.0049	0.0028	0.001
0.000009	0.000085	0.0057	0.0056	0.0017	0	0.0003
0.000004	0.0152	0.0333	0.0015	0.000064	0.000036	0.0003
0	0.0001	0.0049	0.0007	0.000039	0.000082	0.0002
0.003	0.0011	0	0.0052	0.0005	0.000033	0.0072
0.0002	0.0052	0.0289	0.0074	0.0012	0.0013	0.0006
0.0025	0.0067	0.126	0.0052	0.0004	0	0.001
0	0.0013	0.0068	0.0061	0	0.000097	0.0004
0.000028	0	0	0.0051	0	0	0.0137
0.000030	0.0049	0.0266	0.0079	0	0.000022	0.0011
0.000022	0.0008	0.0017	0.0005	0.000050	0.0007	0.0001
0	0.0083	0.017	0.008	0.0006	0	0.0013
0.1339	0.0004	0.0063	0.0022	0	0	0.0065
0.000089	0.1136	0.0163	0.0099	0.001	0.002	0.0022
0.000015	0.0049	0.3017	0.0209	0.0045	0	0.0012
0	0.005	0.1394	0.141	0.043	0.0018	0.0024
0	0.011	0.1136	0.0104	0.1556	0	0.0054
0.000020	0.0071	0.1272	0.0363	0.0334	0.1824	0.0055
0.0014	0.0055	0.0664	0.006	0.0306	0	0.0372
0.000008	0.0606	0.1182	0.0213	0.0295	0.0005	0.0055
0.000022	0.0005	0.0056	0.0052	0.0024	0.0206	0.0013
0.000047	0.0003	0.0015	0.0062	0.0122	0.001	0.0016
0.0002	0.0002	0.0011	0.0021	0.0006	0.0009	0.0021
0.000024	0.000055	0.0003	0.0002	0.0005	0.0001	0.0011
0.0002	0.0023	0.0056	0.0054	0.0052	0.0089	0.0102

21	22	23	24	25	26
0.0113	0.0154	0.0159	0.0496	0.0708	0.022
0.0058	0.0085	0.0438	0.0319	0.0277	0.0368
0.0274	0	0.002	0.0027	0.0386	0.0085
0.0044	0.0231	0.0163	0.0574	0.0071	0.0326
0.0013	0.0069	0.0064	0.0118	0.0099	0.0544
0.0038	0.0096	0.0227	0.0448	0.0101	0.0317
0.0052	0.0214	0.0164	0.0511	0.0087	0.022
0.006	0.0201	0.0197	0.058	0.0217	0.059
0.0087	0.0375	0.0407	0.0566	0.0071	0.0265
0	0.0331	0.0364	0.0501	0.0099	0.0871
0.0066	0.0313	0.047	0.0459	0.0145	0.0693
0.0045	0.0293	0.0177	0.0128	0.0043	0.0085
0.0054	0.0244	0.0256	0.0335	0.0135	0.033
0.0022	0.0095	0.013	0.0273	0.0109	0.032
0.0129	0.0692	0.0634	0.0359	0.0145	0.0352
0.0109	0.0273	0.0366	0.0522	0.0091	0.0241
0.0037	0.0117	0.0149	0.0533	0.0113	0.0369
0.0043	0.0142	0.0186	0.0556	0.0243	0.0492
0.0024	0.011	0.0109	0.036	0.0084	0.0331
0.0031	0.0151	0.0148	0.0438	0.0142	0.0515
0.0008	0.0211	0.0111	0.0828	0.0109	0.087
0.0342	0.1363	0.0154	0.0315	0.022	0.0615
0.0527	0.017	0.175	0.0107	0.015	0.0303
0.0065	0.0219	0.0431	0.0187	0.0567	0.1308
0.0478	0.0032	0.0237	0.0034	0.1284	0.0468
0.0114	0.0142	0.0367	0.0326	0.05	0.0993

Table G.10

Input Requirements : Commodity by Commodity

 $(\tilde{\lambda}^b)$

Commodity> Commodity	1	2	3	4	5	6
1	1.3799	0.0091	0.0634	0.1765	0.000000	0.0046
2	0.0047	1.1316	0.043	0.0056	0.000000	0.0036
3	0.0014	0.0017	1.0029	0.0015	0.000000	0.0005
4	0.5041	0.012	0.0445	1.2657	0.000000	0.0045
5	0.3081	0.0052	0.0269	0.0354	1.2853	0.0036
6	0.0465	0.0099	0.0346	0.0131	0.000000	1.5065
7	0.1796	0.0085	0.042	0.0214	0.000000	0.0048
8	0.0257	0.0156	0.031	0.0133	0.000000	0.0914
9	0.0196	0.0172	0.0598	0.0155	0.000000	0.0238
10	0.0123	0.0102	0.0416	0.0152	0.000000	0.0097
11	0.0158	0.0411	0.0784	0.0256	0.000000	0.0033
12	0.0021	0.003	0.6932	0.0025	0.000000	0.001
13	0.0093	0.0165	0.0496	0.0117	0.000000	0.0477
14	0.0284	0.0053	0.0176	0.0619	0.000000	0.0698
15	0.007	0.0814	0.0543	0.0079	0.000000	0.0079
16	0.0051	0.0789	0.036	0.0065	0.000000	0.0022
17	0.0046	0.0163	0.0224	0.0066	0.000000	0.003
18	0.0059	0.0157	0.0242	0.0084	0.000000	0.0042
19	0.0059	0.0166	0.0213	0.0067	0.000000	0.0223
20	0.0075	0.0109	0.0236	0.0084	0.000000	0.021
21	0.0187	0.0262	0.0384	0.012	0.000000	0.0104
22	0.0055	0.0044	0.1039	0.0083	0.000000	0.0046
23	0.0082	0.0522	0.176	0.0056	0.000000	0.0022
24	0.0104	0.0041	0.0329	0.0131	0.000000	0.0024
25	0.0094	0.0034	0.0122	0.0058	0.000000	0.0015
26	0.0415	0.0059	0.0286	0.0787	0.000000	0.0072

7	8	9	10	11	12	13
0.0063	0.0001	0.0139	0.0036	0.1192	0.0902	0.0119
0.0072	0.000084	0.0052	0.0024	0.024	0.0567	0.013
0.0027	0.000073	0.0012	0.0007	0.007	0.0032	0.0012
0.0086	0.000081	0.0584	0.0099	0.076	0.0594	0.0188
0.0055	0.000047	0.0412	0.0159	0.0464	0.0365	0.0281
0.0041	0.000057	0.0258	0.0043	0.2161	0.0392	0.0212
1.4105	0.000070	0.0113	0.0031	0.0575	0.0577	0.0123
0.1353	1.0049	0.0275	0.005	0.0713	0.0382	0.0563
0.092	0.0001	1.3297	0.0029	0.1066	0.0792	0.0254
0.0305	0.000071	0.4185	1.1739	0.0828	0.0497	0.0187
0.0067	0.000078	0.0399	0.0063	1.4072	0.0748	0.0249
0.0031	0.000076	0.0042	0.001	0.011	1.1059	0.0017
0.0096	0.000064	0.0468	0.004	0.3927	0.0547	1.0559
0.0081	0.000033	0.0267	0.0039	0.0733	0.0204	0.0431
0.0173	0.000099	0.0398	0.0039	0.0673	0.0682	0.0101
0.0082	0.0001	0.0116	0.004	0.0545	0.0428	0.0126
0.0053	0.0002	0.0128	0.0041	0.0265	0.0276	0.0223
0.0068	0.0031	0.0214	0.0067	0.0566	0.0285	0.0401
0.0115	0.0024	0.0092	0.0036	0.0375	0.026	0.0328
0.0157	0.0001	0.0392	0.0046	0.0791	0.0288	0.0333
0.083	0.0022	0.0141	0.0037	0.0454	0.0522	0.017
0.0054	0.0002	0.0065	0.0048	0.014	0.1601	0.0118
0.0073	0.0002	0.0051	0.0037	0.0138	0.097	0.0043
0.0052	0.000060	0.0165	0.008	0.0107	0.0421	0.0058
0.0054	0.0001	0.0063	0.0076	0.0076	0.013	0.0028
0.0046	0.0001	0.0193	0.0155	0.0378	0.0346	0.0106

14	15	16	17	18	19	20
0.0004	0.0062	0.028	0.0183	0.009	0.0072	0.0023
0.000060	0.0062	0.0668	0.0824	0.014	0.0058	0.0029
0.000024	0.0026	0.0167	0.0082	0.004	0.0004	0.0008
0.0002	0.0253	0.0782	0.0142	0.0063	0.005	0.0028
0.0001	0.003	0.0215	0.0078	0.0038	0.0033	0.0023
0.0053	0.0057	0.0211	0.0158	0.0052	0.0036	0.0134
0.0005	0.0115	0.0745	0.0197	0.0067	0.0053	0.0027
0.0033	0.013	0.2041	0.0184	0.0059	0.0032	0.0043
0.0002	0.0063	0.0351	0.0172	0.0049	0.0037	0.0027
0.0002	0.0041	0.0231	0.0163	0.0056	0.0044	0.0197
0.0001	0.0118	0.0718	0.0223	0.006	0.004	0.0043
0.000062	0.0036	0.0179	0.0077	0.0041	0.0025	0.0012
0.0002	0.0149	0.0545	0.0198	0.0053	0.003	0.0041
1.1549	0.0039	0.0244	0.0078	0.0027	0.0018	0.0097
0.0002	1.1323	0.0496	0.025	0.0077	0.0072	0.0048
0.000096	0.0116	1.4572	0.0449	0.0139	0.0031	0.0037
0.000075	0.0109	0.2537	1.1752	0.0538	0.0047	0.0052
0.0001	0.0188	0.2103	0.0245	1.1897	0.0026	0.0089
0.0002	0.0145	0.2541	0.0628	0.0555	1.2254	0.0094
0.0018	0.0102	0.119	0.0152	0.0414	0.0023	1.041
0.0002	0.0732	0.1996	0.0374	0.0414	0.0043	0.0089
0.0001	0.0056	0.0322	0.0132	0.0089	0.0311	0.0037
0.0001	0.0069	0.0297	0.0179	0.0231	0.0035	0.0039
0.0003	0.0027	0.0121	0.0064	0.0045	0.0041	0.0047
0.000069	0.0048	0.0147	0.0038	0.0044	0.0015	0.0027
0.0003	0.0071	0.0285	0.0121	0.0111	0.0137	0.0132

21	22	23	24	25	26
0.0324	0.0449	0.0563	0.098	0.1338	0.0826
0.0182	0.024	0.0777	0.056	0.0517	0.0739
0.031	0.0032	0.0076	0.009	0.0475	0.0189
0.0265	0.0634	0.0661	0.1249	0.0751	0.1047
0.0145	0.0285	0.0375	0.0491	0.0549	0.1108
0.0186	0.0371	0.0723	0.096	0.0429	0.1001
0.021	0.0532	0.0544	0.102	0.0476	0.0754
0.0216	0.0501	0.063	0.1022	0.0528	0.1163
0.0269	0.0773	0.0931	0.1045	0.036	0.0851
0.0193	0.0798	0.0951	0.1078	0.044	0.1678
0.0266	0.0691	0.1074	0.0915	0.0507	0.1466
0.0303	0.0422	0.0332	0.0252	0.0428	0.0326
0.0214	0.0587	0.0769	0.0757	0.0429	0.1003
0.011	0.0269	0.0392	0.0551	0.0311	0.0713
0.0319	0.1079	0.1142	0.0685	0.0424	0.0868
0.0285	0.06	0.0875	0.0978	0.0368	0.0783
0.0161	0.0351	0.0504	0.0928	0.036	0.0857
0.0185	0.0404	0.0585	0.0964	0.0551	0.1055
0.0147	0.0362	0.0472	0.0789	0.0329	0.0846
0.0141	0.0363	0.0461	0.0734	0.0367	0.0955
1.0162	0.0529	0.0544	0.1232	0.0431	0.1467
0.0508	1.1727	0.0405	0.056	0.0485	0.1061
0.0756	0.0357	1.2297	0.0338	0.0417	0.0687
0.0194	0.0358	0.0696	1.0346	0.083	0.1666
0.0598	0.0111	0.0417	0.0167	1.1568	0.0742
0.0249	0.0321	0.0677	0.0583	0.0798	1.1435

Table G.11

U.S. Capital Stock: 26 - Sector Aggregation, 1980
(Millions of Dollars--Current Price)

Industry Number	Capital Stock [*]
1	171705.5
2	37400
3	137292
4	52705.5
5	2936
6	22767
7	15177.5
8	4832.5
9	36685.5
10	18859.5
11	76899
12	36612
13	6608
14	715
15	28287
16	111988
17	54042
18	38945
19	58349.5
20	17192
21	54798.5
22	238415.5
23	544936
24	234693
25	452454.5
26	200895

* The mid-year net capital stock

Source: Table G.12

Table G.12

U.S. Net Capital Stock by Input-Output Industry, 1980
(Millions of Dollars--Current Price)

Industry	SIC Code (1972)	Mid-Year Net Capital Stock
1 Manufacturing		
2 Non-farm Manufacturing		
3 All Industries		
4 Farms	01, 02	158617
5 Agricultural Services, Forestry, Fisheries	07, 08, 09	13088.5
6 Metal Mining	10	13812.5
7 Coal Mining	11, 12	18572
8 Oil & Gas Extraction	13	137292
9 Non-metallic Minerals except Fuels	14	9000.5
10 Construction	15, 16, 17	54798.5
11 Lumber and Wood Products	24	15177.5
12 Furniture and Fixtures	25	4832.5
13 Stone, Clay and Glass Products	32	24302
14 Primary Metal Industries	33	73991.5
15 Fabricated Metal Products	34	37996.5
16 Machinery except Electrical	35	54042
17 Electrical and Electronic	36	38945
18 Motor Vehicles and Equipment	371	36858
19 Transportation Equipment Motor Vehicles	37 except 371	21491.5
20 Instruments and Related Products	38	10923

	Industry	SIC Code (1972)	Mid-Year Net Capital Stock *
21	Miscellaneous Manufacturing Industries	39	6269
22	Food and Kindred Products	20	52705.5
23	Tobacco Manufactures	21	2936
24	Textile Mill Products	22	16759.5
25	Apparel & Other Textile Products	23	6007.5
26	Paper and Allied Products	26	36685.5
27	Printing and Publishing	27	18859.5
28	Chemicals and Allied Products	28	76899
29	Petroleum & Coal Products	29	36612
30	Rubber & Miscellaneous Plastic Products	30	18720.5
31	Leather and Leather Products	31	1353
32	Railroad Transportation	40	98169.5
33	Local & Interurban Passenger Transit	41	3846.5
34	Trucking and Warehousing	42	39856
35	Water Transportation	44	29534
36	Transportation by Air	45	30122.5
37	Pipelines except Natural Gas	46	19876
38	Transportation Services	47	17011
39	Telephone & Telegraph	481, 482, 489	190360
40	Radio & Television Broadcasting	483	10754
41	Electric Services	491, part of 493	266044.5
42	Gas Services	492, part of 493	68553
43	Sanitary Services	494, 495, 496, 497	9224.5
44	Wholesale Trade	50, 51	86887.5
45	Retail Trade	52 - 59	147805.5
46	Federal Reserve Banks	601	764.5
47	Commercial & Mutual Banks, Banking	60 except 601	44392.5

	Industry	SIC Code (1972)	Mid-Year Net Capital Stock *
48	Credit Agencies other than Banks	61	35669
49	Security, Commodity Brokers & Services	62	1676.5
50	Insurance Carriers	63	9797
51	Insurance Agents, Brokers & Services	64	2420.5
52	Real Estate	65, 66	317576
53	Holding & other Investment Companies,	67	4482.5
54	RICS, SBICS, and REITS	pt. 67	1372
55	Hotels and other Lodging Places	70	34304
56	Personal Services	72	11044
57	Business Services	73	44634
58	Auto Repair, Services & Garages	75	32951
59	Miscellaneous Repair Services	76	5450.5
60	Motion Pictures	78	4552
61	Amusement & Recreation Services	79	15404.5
62	Health Services	80	28145.5
63	Legal Services	81	3454
64	Educational Services	82	1089
65	Social Services	83, 84, 86, 89	19866.5
66	Other Services	-	0

- * The sum of Equipment and Structure valued at the mid-year of 1980. They are derived from the raw data provided by the Bureau of Economic Analysis, the U.S. Department of Commerce.

Table G.13

U.S. Employment: 26 - Sector Aggregation, 1980
(Thousands)

Industry Number	Employments
1	1791
2	479
3	562
4	1716
5	67
6	2127
7	707
8	468
9	691
10	1274
11	1116
12	203
13	727
14	242
15	668
16	2768
17	2491
18	2107
19	1907
20	1144
21	4466
22	2987
23	2180
24	20754
25	5347
26	19859

Source: Table G.14

Table G.14

Full-Time and Part-Time Employees by Industry, 1980
(Thousands)

Industry		Employments
1	Manufacturing	20423
2	Non-farm Manufacturing	
3	All Industries	
4	Farms	1246
5	Agricultural Services, Forestry, Fisheries	545
6	Metal Mining	100
7	Coal Mining	252
8	Oil & Gas Extraction	562
9	Non-metallic Minerals except Fuels	127
10	Construction	4466
11	Lumber and Wood Products	707
12	Furniture and Fixtures	468
13	Stone, Clay and Glass Products	668
14	Primary Metal Industries	1151
15	Fabricated Metal Products	1617
16	Machinery except Electrical	2491
17	Electrical and Electronic	2107
18	Motor Vehicles and Equipment	798
19	Transportation Equipment Motor Vehicles	1109
20	Instruments and Related Products	707
21	Miscellaneous Manufacturing Industries	437
22	Food and Kindred Products	1716
23	Tobacco Manufactures	67
24	Textile Mill Products	852
25	Apparel & Other Textile Products	1275
26	Paper and Allied Products	691

Industry		Employments
27	Printing and Publishing	1274
28	Chemicals and Allied Products	1116
29	Petroleum & Coal Products	203
30	Rubber & Miscellaneous Plastic Products	727
31	Leather and Leather Products	242
32	Railroad Transportation	512
33	Local & Interurban Passenger Transit	277
34	Trucking and Warehousing	1303
35	Water Transportation	212
36	Transportation by Air	457
37	Pipelines except Natural Gas	22
38	Transportation Services	204
39	Telephone & Telegraph	1156
40	Radio & Television Broadcasting	199
41	Electric Services, Gas Services, Sanitary Services	825
42	Wholesale Trade	5335
43	Retail Trade	15419
44	Federal Reserve Banks, Commercial & Mutual Banks, Banking	1576
45	Credit Agencies other than Banks	571
46	Security, Commodity Brokers & Service	233
47	Insurance Carriers	1276
48	Insurance Agents, Brokers & Services	471
49	Real Estate	1101
50	Holding & other Investment Companies, RICS, SBICS, and REITS	119
51	Hotels and other Lodging Places	1137
52	Personal Services	973

Industry		Employments
53	Business Services	3135
54	Auto Repair, Services & Garages	622
55	Miscellaneous Repair Services	308
56	Motion Pictures	224
57	Amusement & Recreation Services	791
58	Health Services	5398
59	Legal Services	551
60	Educational Services	1310
61	Social Services	1123
62	Other Services	4287

Source: National Income and Product Accounts of the United States, 1929-82, Bureau of Economic Analysis, U.S. Department of Commerce, 1986.

Table G. 15

Direct Factor Requirements: Industry by Factor

 $(\bar{d}^b)$

G1	G2	G3	G4	G5	G6	G7	G8
0.390158	0.182865	0.062515	0.303590	8.410311	0.118237	0.432911	0.949182
0.604206	0.622873	0.045363	0.717764	0.007366	0.222997	8.737140	0.855570
0.730313	0.573726	0.076918	0.702947	0.003275	0.066239	2.690626	1.183360
0.230129	0.633370	0.256924	0.761146	0.007479	0.312979	4.625217	0.209693
0.217738	0.313155	0.175410	0.446776	0.009087	0.153050	2.690401	0.175529
0.461977	1.044951	0.405212	1.854192	0.006203	0.389771	16.65118	0.222783
0.278995	1.102014	0.240352	0.984455	1.960918	0.340098	10.45051	0.329683
0.459117	1.520112	0.584965	2.156772	0.019569	0.394223	16.31335	0.221470
0.503212	0.748498	0.289059	1.115217	0.022289	0.225916	6.704238	0.510115
2.507480	2.056411	2.116785	3.698309	0.003759	0.238952	7.592066	0.269625
1.133931	0.854829	0.348907	1.089443	0.006340	0.213888	3.500415	0.492522
0.148207	0.131922	0.019122	0.160725	0.000913	0.029880	0.545214	0.186845
0.903374	1.334833	0.321274	1.749048	0.006528	0.379362	10.91729	0.141901
0.377411	1.242324	0.639252	2.547706	0.008786	0.338336	19.86220	0.073910
0.798459	1.301906	0.379703	1.518502	0.007562	0.344842	10.46282	0.627302
0.595682	0.752123	0.217381	1.256297	0.004600	0.266049	8.288418	0.460435
1.690934	1.382422	0.380221	1.932765	0.005797	0.243524	8.426332	0.305073
2.501469	1.511368	0.320423	2.232866	0.008630	0.276261	9.270016	0.297975
1.299909	0.701398	0.098275	1.117763	0.004213	0.226573	6.163166	0.294082
2.004703	1.941948	0.721559	2.768646	0.008401	0.310862	10.14245	0.268979
0.500627	0.832847	0.116213	0.794962	0.019172	0.095077	9.787904	0.149043
0.645788	1.360769	0.631293	2.841474	0.012762	0.715974	9.918304	1.287169
0.760498	0.608521	0.153410	2.768088	0.007252	0.177532	2.375357	1.712464
1.090948	4.112204	15.30894	5.530908	0.051112	0.854224	10.08910	0.418831
0.320604	1.984334	2.205703	4.204502	0.049191	0.388252	0.214396	0.792619
8.035264	2.090418	0.556127	3.212860	0.075945	5.116112	1.795985	0.269408

Table G.16

Direct Factor Requirements: Commodity by Factor

(a^b)

G1	G2	G3	G4	G5	G6	G7	G8
0.39	0.1652	0.0553	0.2849	8.7106	0.1075	0.2792	0.9755
0.5866	0.6117	0.0334	0.7016	0.0074	0.2227	8.9076	0.8695
0.7847	0.6086	0.0863	0.6621	0.0035	0.0755	2.8561	1.2238
0.2266	0.6321	0.2564	0.7591	0.0072	0.3134	4.6235	0.2086
0.2171	0.3124	0.1753	0.4454	0.0091	0.1529	2.6811	0.175
0.4482	1.045	0.4045	1.8646	0.0054	0.3944	16.8993	0.2179
0.2716	1.103	0.2391	0.9777	1.9871	0.3409	10.472	0.329
0.4348	1.53	0.5925	2.1709	0.0115	0.3972	16.5303	0.2177
0.4841	0.7247	0.2717	1.0786	0.0201	0.2354	6.5946	0.5186
0	2.0558	3.1119	4.0407	0	0	11.1385	0.2674
1.1502	0.8559	0.3513	1.0867	0.0062	0.2151	3.3996	0.5009
0.0711	0.0755	0	0.0885	0.0005	0.0154	0.3151	0.1624
0.8944	1.3505	0.3169	1.761	0.0059	0.3884	11.0844	0.1273
0.3693	1.243	0.6433	2.5644	0.0035	0.3399	20.0298	0.0695
0.7912	1.3134	0.3835	1.5254	0.0058	0.3483	10.5622	0.6337
0.5704	0.7369	0.2107	1.2393	0.0036	0.2696	8.2958	0.4638
1.7023	1.3971	0.3849	1.9458	0.0053	0.2432	8.4299	0.3026
2.5639	1.5295	0.3194	2.2605	0.0086	0.2777	9.3157	0.2959
1.2917	0.6796	0.0887	1.0893	0.004	0.2252	6.055	0.2919
1.9641	1.9888	0.7442	2.8301	0.0066	0.2535	10.3776	0.2636
0.5006	0.8328	0.1162	0.795	0.0192	0.0951	9.7879	0.149
0.6483	1.3699	0.6381	2.8436	0.0101	0.7241	9.9976	1.282
0.3901	0.4736	0	2.7081	0.0028	0	2.2362	1.8174
1.0909	4.1122	15.3089	5.5309	0.0511	0.8542	10.0891	0.4188
0.3068	1.9841	2.2087	4.2063	0.0491	0.3798	0.2116	0.7936
8.0499	2.0906	0.553	3.211	0.076	5.1251	1.799	0.2684

Table G.17

Price of Selected Agricultural Products^{*}
(US dollars)

Products	Country			Price Ratio	
	US	CAN	UK	pcan/pus	puk/pus
Wheats	14.37	17.02	23.58	1.184	1.641
Rye	10.39	14.57	24.27	1.402	2.336
Barley	13.09	11.79	22.08	0.901	1.687
Oats	12.33	10.54	23.40	0.855	1.898
Maize	12.24	12.76	-	1.042	-
Potatoes	11.00 ^{**}	8.89	11.95	0.808	1.086
Sugar Beet	5.20	5.21	6.66	1.002	1.281
Cattle	137.57	133.51	175.06	0.970	1.273
Pigs	83.77	109.28	148.54	1.305	1.773
Fowls	61.07	102.77	117.64	1.683	1.926
Whole Milk	28.66	27.05	29.54	0.944	1.031

* Weighted average prices received by farmers per 100 kg for all types and all sales; 1980/81 agricultural year (except potatoes and cattle which are referred to the calendar year).

** US price of potatoes is converted to refer to the calendar year.

Source: Prices of Agricultural Products and Selected Inputs in Europe and North America, 1981/82, Annual ECE/FAO Price Review No.32, UN 1983.

Table G.18

Trade in Agricultural Primary Products, 1980

Value(V): Millions of US dollars

Quantity(Q): Thousands of metric tons

Price(P): US dollar/ Metric ton

Products		Import		Export		Price Ratio (p _{JAP} /p _{US})
		US	JAP	US	JAP	
Wheat	V		1,236.2	6,587.3		1.218
	Q		5,682	36,862		
	P		217.6	178.7		
Maize	V		2,010.5	8.571		1.155
	Q		12,830	63,157		
	P		156.7	135.7		
Sugar	V	1,987.7	1,210.7			1.003
	Q	3,721	2,260			
	P	534.2	535.7			
Banana	V	429.8	192.4			1.494
	Q	2,423	726			
	P	177.4	265			
Coffee	V	3,945.8	669			1.073
	Q	1,107	175			
	P	3,564.4	3,822.9			
Cocoa	V	395.3	71.2			1.183
	Q	151	23			
	P	2,617.9	3,095.7			

Products		Import		Export		Price Ratio (pJAP/pUS)
		US	JAP	US	JAP	
Tea	V	129.9	63.5			2.566
	Q	84	16			
	P	1,546.4	3,968.8			
Pepper	V	59.7	12.5			1.017
	Q	34	7			
	P	1,755.9	1,785.7			
Vegetable Oilseeds	V		2,075.8	7,827.5		1.039
	Q		1,681	6,589		
	P		1,234.9	1,188		
Groundnuts	V		63.9	208.1		1.411
	Q		62	285		
	P		1,030.6	730.2		
Soyabeans	V		1,321.3	5,882.9		1.112
	Q		4,401	21,786		
	P		300.2	270		

Source: Yearbook of International Commodity Statistics 1984,
United Nations 1984.

Table G.19

Price of Selected Mining Products, 1980
(Average US cents / Pound)

Products	Country			Price Ratio [*]	
	US	CAN	UK	p _{CAN} /p _{US}	p _{UK} /p _{US}
Aluminum	69,566	69,566	80,753	1.00	1.161
Copper	101,374	100,596	99,297	0.992	0.98
Iron Ore ^{**}	73.66	69.562	74.48	0.944	1.011
Lead	42,456	42,174	41,213	0.993	0.97
Silver	2,063.15	2,063,705	2,085.31	1.00	1.01
Tin	773,437	855,384	763,087	1.106	0.987
Zinc	37,428	37,453	34,482	1.001	0.921

* Unweighted average price ratio.

** Average US cents / 1tu.

Source: Minerals Yearbook 1980, Bureau of Mines.

Table G.20
Price of Oil and Gas for Industry, 1980^{*}
(US dollars)

Products	Country				Unit
	US	CAN	UK	JAP	
	A. Price				
Light Fuel Oil	212.73 ** (0.643)	136.87 (1.404)	298.70 (1.466)	311.87 (1.466)	1000 litres
Heavy Fuel Oil	143.30 ** (0.679)	97.44 (1.489)	213.51 (1.873)	268.38 (1.873)	metric ton
Natural Gas	98.63 ** (0.663)	65.38 (1.644)	162.14 (4.549)	448.73 (4.549)	10 ⁷ Kcal
	B. Consumption				
Oil	129,080	15,313	16,879	59,407	1000 metric ton
Natural Gas	1,684,136	180,070	150,003	16,340	Tcal

* End-user prices are actually paid by industry which are prepared by the International Energy Agency to ensure comparability between countries.

** The figures in parentheses are price ratio of corresponding country to the U.S.

Source: Energy Prices and Taxes, Fourth Quarter 1990,
International Energy Agency, OECD 1991.

Energy Statistics of OECD Countries, 1987-1988,
International Energy Agency, OECD 1990.

To calculate weighted average price ratio of light fuel oil, heavy fuel oil and natural gas we assume that consumption of oil is divided into light fuel oil and heavy fuel oil at the same proportion.

$$\begin{aligned}
 \text{pcan/pus} &: [(0.643 \times 136,870 \times 15,313 \div 2) \\
 &\quad + (0.679 \times 97,440 \times 15,313 \div 2) \\
 &\quad + (0.663 \times 6,538 \times 180,070)] \div 2,971,292,175 \\
 &= 0.66
 \end{aligned}$$

$$\begin{aligned}
 \text{puk/pus} &: [(1.404 \times 298,700 \times 16,879 \div 2) \\
 &\quad + (1.489 \times 213,510 \times 16,879 \div 2) \\
 &\quad + (1.644 \times 16,214 \times 150,003)] \div 6,754,944,937 \\
 &= 1.513
 \end{aligned}$$

$$\begin{aligned}
 \text{pjap/pus} &: [(1.466 \times 311,870 \times 59,407 \div 2) \\
 &\quad + (1.873 \times 268,380 \times 59,407 \div 2) \\
 &\quad + (4.549 \times 44,873 \times 16,340)] \div 17,968,680,700 \\
 &= 1.768
 \end{aligned}$$

Table G.21
Data on Imports by Industry from US, 1980

Industry Numbers	SIC Codes	Country	Value (US dollars)
1	01, 02 07 - 09	CAN UK JAP	990,239,208 625,365,960 4,882,593,262
2	10 - 12, 14	CAN UK JAP	1,366,018,863 301,224,877 1,756,401,578
3	13	CAN UK JAP	750,555,385 3,473 218,061,448
4	20	CAN UK JAP	975,882,400 355,928,711 1,610,792,920
5	21	CAN UK JAP	9,013,670 8,466,876 44,442,937
6	22, 23	CAN UK JAP	584,814,057 375,025,705 151,288,165
7	24	CAN UK JAP	387,426,202 61,308,868 1,916,895,645
8	25	CAN UK JAP	118,071,844 30,530,043 7,866,313
9	26	CAN UK JAP	445,278,995 308,512,927 611,281,342
10	27	CAN UK JAP	473,765,464 131,300,316 38,806,600

Industry Numbers	SIC Codes	Country	Value (US dollars)
11	28	CAN UK JAP	2,166,779,709 772,120,968 1,877,019,712
12	29	CAN UK JAP	251,118,238 80,946,587 258,424,792
13	30	CAN UK JAP	635,185,719 126,247,250 127,001,395
14	31	CAN UK JAP	55,552,026 27,328,619 27,592,070
15	32	CAN UK JAP	576,628,224 83,132,045 72,356,909
16	33, 34	CAN UK JAP	3,900,450,080 2,261,686,508 1,200,316,193
17	35	CAN UK JAP	6,788,960,848 2,467,119,446 1,622,711,602
18	36	CAN UK JAP	2,040,395,677 1,022,701,276 787,199,564
19	37	CAN UK JAP	8,248,562,848 1,747,430,162 1,350,474,359
20	38, 39	CAN UK JAP	1,320,804,843 901,287,414 1,047,127,240

Industry Numbers	SIC Codes	Country	Value (US dollars)
21	15 - 17	CAN UK JAP	0 0 0
22	40 - 42, 44 - 47	CAN UK JAP	0 0 0
23	43, 48, 49	CAN UK JAP	0 0 0
24	50 - 57, 59	CAN UK JAP	0 0 0
25	60 - 67	CAN UK JAP	0 0 0
26	58, 70 - 89	CAN UK JAP	0 0 0

Source: U.S. Exports: FT 610, U.S. Department of Commerce,
Bureau of the Census, May 1985.

Table G.22

Customs and Imports Duties*

Country	Value	Description
US	\$ 3,010 (1979)	Data are on a fiscal
	\$ 7,436 (1980)	Data are on a fiscal
	\$ 8,161 (1981)	year basis: fiscal year
	(in millions of US dollar)	ends September 30
CAN	\$ 3,199 (1980) (in millions of Cdn. dollar)	year basis: fiscal year begins 1st April
UK	£ 1,179 (1980) (in millions of pound sterling)	Data refer to a calendar year ending 31st December
JAP	¥ 856 (1979)	Data refer to a fiscal
	¥ 786 (1980)	year beginning
	(in billions of Yen)	1st April

- * Taxes, Stamp duties and surcharges restricted by law to imported products are included. Also included are levies on imported agricultural products which are imposed in Member countries of the European countries.

Source: Revenue Statistics of OECD Member Countries, 1965 - 1985, OECD 1987.

Table G.23

Tariff Revenues in 1980
(Millions of US dollars)

Country	Total Customs and Import Duties [*]	Imports from the US ^{**}	Non-Primary Imports/ Total Imports ^{***}	$R_{\delta\Sigma}$
US	7,617.25	-	-	-
CAN	2,693.80	(70.34%)	(90.32%)	1711.401
UK	2,741.86	(11.77%)	(92.07%)	297.126
JAP	3,544.33	(17.40%)	(65.03%)	401.048

* Values are recalculated to refer to the calendar year (Source: Table G.22).

** Each country's percentage of imports from the United States to its total imports is derived from OECD Monthly Statistics of Foreign Trade, Series A, OECD 1983.

*** Each country's ratio of its imports of non-primary goods to its total imports is derived from Table G.21.

Country	US Total Customs and Import Duties	US Noncompetitive (Intermediate) Imports *	US Exports to Country a **	US Non- Primary Exports / Total Production ***	$Q_{\alpha\Sigma}^*$
US-CAN	7,617.25	(6.38%)	(16%)	(3.4%)	2.65
US-UK	7,617.25	(6.38%)	(5.8%)	(3.4%)	0.96
US-JAP	7,617.25	(6.38%)	(9.4%)	(3.4%)	1.55

* Ratio of the US noncompetitive imports used as intermediate inputs in the production of the non-primary goods to its total imports is derived from the 1980 U.S. Use Table.

** Ratio of the US exports to country a to its total exports is obtained from OECD Monthly Statistics of Foreign Trade, Series A, OECD 1983.

*** Ratio of the US non-primary exports to the US total production is calculated from the 1980 US Use table and U.S. Exports: FT 610.

G.2 Basic Data on Wage Rates by Occupational Groupings

This Section presents a full description of sources and adjustment methodology for compiling the data on average wages and salaries by occupational groupings in 1980.

A. US

The United States census reports mean earnings in 1979 of employed persons. The United States figures are therefore adjusted to represent 1980 data by augmenting 1979 values by 10.84% which is estimates of increases between 1979 and 1980 in earnings of workers obtained from Jorgenson and Kuroda (1990).

Average Wages and Salaries by Occupational Groupings in 1979:

US \$

$$\begin{aligned}
 G1: & \text{Professional} \quad 23739 \times \frac{6133501}{16726923} + 10958 \times \frac{5884596}{16726923} \\
 & + \text{Technical} \quad 17326 \times \frac{1679062}{16726923} + 9524 \times \frac{1302889}{16726923} \\
 & + \text{Health} \quad 9177 \times \frac{205246}{16726923} + 6019 \times \frac{1521629}{16726923} \\
 & = 15700.873
 \end{aligned}$$

$$\begin{aligned}
 G2: & 25671 \times \frac{7063304}{10133551} + 11863 \times \frac{3070247}{10133551} \\
 & = 21487475
 \end{aligned}$$

$$\begin{aligned}
 G3: & 18412 \times \frac{5088664}{9760157} + 5993 \times \frac{4671493}{9760157} \\
 & = 12469344
 \end{aligned}$$

$$\begin{aligned}
 G4: & 14355 \times \frac{38543224}{16851398} + 8070 \times \frac{12997076}{16851398} \\
 & = 95075314
 \end{aligned}$$

$$\begin{aligned}
 G5: \text{ Farming} & \quad 10525 \times \frac{2406989}{4033436} + 4253 \times \frac{404269}{4033436} \\
 + \text{ Laborer} & \quad 10401 \times \frac{986498}{4033436} + 6479 \times \frac{235680}{4033436} \\
 = & \quad 9629619
 \end{aligned}$$

G6: Stage 1

To get the average for service without Heath Service

	Male	Female
Food	$5607 \times \frac{1479935}{3639414}$	$3852 \times \frac{2905001}{5198469}$
+ Cleaning	$8943 \times \frac{1782033}{3639414}$	+ $4932 \times \frac{963370}{5198469}$
+ Personal	$9424 \times \frac{377446}{3639414}$	+ $5071 \times \frac{1330098}{5198469}$
	= 7636	= 4364

Stage 2

$$\begin{aligned}
 \text{Private} & \quad 4981 \times \frac{26466}{10902550} + 2674 \times \frac{562886}{10902550} \\
 + \text{Protective} & \quad 14530 \times \frac{1306454}{10902550} + 6880 \times \frac{168861}{10902550} \\
 + \text{Service} & \quad 7636 \times \frac{3639414}{10902550} + 4364 \times \frac{5198469}{10902550} \\
 = & \quad 66276429
 \end{aligned}$$

$$\begin{aligned}
 G7: & \quad 16632 \times \frac{23614770^*}{29231340} + 7822 \times \frac{5616570^{**}}{29231340} \\
 = & \quad 14939228
 \end{aligned}$$

* Total Male (56004690) - Subtotal of 1-6 Male (32389920)

** Total Female (41634665) - Subtotal of 1-6 Female (36018095)

Source: Census of Population: Occupation by Industry 1980,
(pc80-2-7c).

Average increase in the wage rate from 1979 to 1980 in the
United States:

Labour	Input Price Index	% Increase
1979	2.00071	-
1980	2.21758	10.84 %

Source: Jorgenson and Kuroda (1990), "Productivity and International Competitiveness in Japan and the United States, 1960-1985", in Productivity Growth in Japan and the United States, ed. C.R. Hulten.

Annual Average Earnings by Occupational Groupings for the
United States, 1980:

	<u>US \$</u>		<u>% Increase</u>		<u>US \$</u>
G1:	15701	x	1.1084	=	17402.99
G2:	21488	x	1.1084	=	23817.30
G3:	12469	x	1.1084	=	13820.64
G4:	9508	x	1.1084	=	10538.67
G5:	9630	x	1.1084	=	10673.89
G6:	6628	x	1.1084	=	7346.48
G7:	14939	x	1.1084	=	16558.39

B. Canada

Canada Census reports average earnings in 1980 of employed persons.

Average Wages and Salaries by Occupational Groupings in 1980:

Cdn \$

$$\begin{aligned}
 & \text{G1:} \quad (21) \quad 25850 \times \frac{239155}{985400} + 18126 \times \frac{28930}{985400} \\
 & \quad + (23) \quad -26107 \times \frac{44640}{985400} + 17301 \times \frac{41400}{985400} \\
 & \quad + (25) \quad 12707 \times \frac{16885}{985400} + 12193 \times \frac{3545}{985400} \\
 & \quad + (27) \quad 26728 \times \frac{160890}{985400} + 20745 \times \frac{167720}{985400} \\
 & \quad + (31) \quad 23935 \times \frac{49405}{985400} + 16305 \times \frac{171335}{985400} \\
 & \quad + (33) \quad 20706 \times \frac{41680}{985400} + 15787 \times \frac{19815}{985400} \\
 & \quad = 22100.256 \\
 \\
 & \text{G2:} \quad 29396 \times \frac{607135}{773130} + 17807 \times \frac{165995}{773130} \\
 & \quad = 26907.782 \\
 \\
 & \text{G3:} \quad 21215 \times \frac{350175}{482555} + 12042 \times \frac{132380}{482555} \\
 & \quad = 18698.558 \\
 \\
 & \text{G4:} \quad 17470 \times \frac{302640}{1132550} + 12547 \times \frac{829910}{1132550} \\
 & \quad = 13862.524 \\
 \\
 & \text{G5:} \quad (71) \quad 12869 \times \frac{37910}{62010} + 8886 \times \frac{6955}{62010} \\
 & \quad + (73) \quad 16830 \times \frac{1980}{62010} + \quad \quad \quad \text{N/A} \\
 & \quad + (75) \quad 21512 \times \frac{14880}{62010} + 14911 \times \frac{285}{62010} \\
 & \quad = 14632.116
 \end{aligned}$$

3

of/de

3

PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
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$$\begin{aligned} \text{G6:} \quad & 17270 \times \frac{328795}{518400} + 9568 \times \frac{189605}{518400} \\ & = 14452.991 \end{aligned}$$

$$\begin{aligned} \text{G7:} \quad & 21623 \times \frac{1553780^*}{1754255} + 13773 \times \frac{200475^{**}}{1754255} \\ & = 20725.908 \end{aligned}$$

* Total Male (3749950) - Subtotal of 1 - 6 Male (2196170)

** Total Female (1958350) - Subtotal of 1 - 6 Female (1757875)

Source: Census of Canada 1981, Worked in 1980 - employment income by occupation, (92-930).

Annual average Earnings by Occupational Groupings for Canada,

1980:

	<u>Cdn \$</u>		<u>Exchange Rate</u>		<u>US \$</u>
G1:	22100	÷	1.17	=	18888.89
G2:	26908	÷	1.17	=	22998.29
G3:	18699	÷	1.17	=	15982.05
G4:	13863	÷	1.17	=	11848.72
G5:	14632	÷	1.17	=	12505.98
G6:	14453	÷	1.17	=	12352.99
G7:	20726	÷	1.17	=	17714.53

C. UK

The United Kingdom survey information relates to average weekly earnings of a group of employees in April 1980. The increase (percentage) between April 1980 and 1981 in average earnings of a particular group of workers is obtained by comparing corresponding published 1979 and 1980 survey results. We thus augment 1980 figures by a quarter of the corresponding annual rate for each group.

Average Gross Weekly Earnings by Occupation in April 1980:

£

$$\begin{aligned}
 \text{G1:} \quad & 149.5 \times \frac{4563}{19524} + 154.5 \times \frac{698}{19524} + 153.0 \times \frac{6728}{19524} \\
 & + 106.0 \times \frac{6854}{19524} + 109.0 \times \frac{186}{19524} + 100.7 \times \frac{495}{19524} \\
 & = 133.98
 \end{aligned}$$

$$\begin{aligned}
 \text{G2:} \quad & 173.5 \times \frac{5850}{14255} + 150.4 \times \frac{6631}{14255} \\
 & + 125.4 \times \frac{904}{14255} + 93.6 \times \frac{870}{14255} \\
 & = 154.82
 \end{aligned}$$

$$\begin{aligned}
 \text{G3:} \quad & 116.2 \times \frac{3216}{5494} + 61.8 \times \frac{2278}{5494} \\
 & = 93.64
 \end{aligned}$$

$$\begin{aligned}
 \text{G4:} \quad & 107.5 \times \frac{7081}{22803} + 76.9 \times \frac{15722}{22803} \\
 & = 86.40
 \end{aligned}$$

$$\text{G5:} \quad 89.00$$

$$\begin{aligned}
 \text{G6:} \quad & 140.0 \times \frac{2052}{8901} + 96.0 \times \frac{2923}{8901} \\
 & + 109.2 \times \frac{160}{8901} + 66.2 \times \frac{3766}{8901} \\
 & = 93.78
 \end{aligned}$$

$$\begin{aligned}
 \text{G7:} \quad & 114.7 \times \frac{2814}{45184} + 113.0 \times \frac{3667}{45184} + 122.4 \times \frac{15073}{45184} \\
 & + 110.0 \times \frac{3668}{45184} + 116.7 \times \frac{3743}{45184} + 113.5 \times \frac{9198}{45184} \\
 & + 108.0 \times \frac{1353}{45184} \\
 & + 68.4 \times \frac{667}{45184} + 67.8 \times \frac{1547}{45184} + 76.5 \times \frac{669}{45184} \\
 & + 72.3 \times \frac{2400}{45184} + 80.1 \times \frac{385}{45184} \\
 & = 111.05
 \end{aligned}$$

-
- * The figures in parentheses are average gross weekly earnings by occupation in 1980 that are obtained by multiplying the average gross weekly earnings in April 1980 by a quarter increase in percentage term for each group. Table 8 in New Earnings Survey 1981 presents, for each occupation, percentage increase in earnings from April 1980 to April 1981.

Source: New Earnings Survey 1980, Part D Analyses by Occupation.

Annual average Earnings by Occupational Groupings for the
United Kingdom

	<u>£</u>	<u>weeks</u>		<u>£</u>	<u>Exchange Rate</u>		<u>US \$</u>
G1:	133.98	× 52	=	6966.96	+ 0.43	=	16202.23
G2:	154.82	× 52	=	8050.64	+ 0.43	=	18722.42
G3:	93.64	× 52	=	4869.28	+ 0.43	=	11323.91
G4:	86.40	× 52	=	4492.80	+ 0.43	=	10448.37
G5:	89.00	× 52	=	4628	+ 0.43	=	10762.79
G6:	93.78	× 52	=	4876.56	+ 0.43	=	11340.84
G7:	111.05	× 52	=	5774.60	+ 0.43	=	13429.30

D. Japan

Japan Statistical Yearbook reports average monthly earnings in 1980 of employed persons.

Average Monthly Contract Cash Earnings by Occupation, 1980:

$$\begin{array}{l}
 \text{1,000 ¥} \\
 \hline
 \text{G3:} \quad 186.9 \times \frac{7558}{76845} + 214.6 \times \frac{2929}{76845} + 219.5 \times \frac{4136}{76845} \\
 \quad + 112.6 \times \frac{4128}{76845} + 122.9 \times \frac{12513}{76845} + 115.6 \times \frac{22631}{76845} \\
 \quad + 176.8 \times \frac{22950}{76845} \\
 \quad = 151.283 \\
 \\
 \text{G4:} \quad 130.4 \times \frac{2323}{13108} + 140.2 \times \frac{517}{13108} + 122.7 \times \frac{5786}{13108} \\
 \quad + 132.2 \times \frac{4492}{13108} \\
 \quad = 128.005 \\
 \\
 \text{G6:} \quad 202.7 \times \frac{5946}{57948} + 169.4 \times \frac{3809}{57948} + 184 \times \frac{10828}{57948} \\
 \quad + 120.7 \times \frac{2715}{57948} + 154.4 \times \frac{5101}{57948} + 133.2 \times \frac{2113}{57948} \\
 \quad + 107.1 \times \frac{4366}{57948} + 120 \times \frac{11080}{57948} + 138 \times \frac{5147}{57948} \\
 \quad + 96.8 \times \frac{6843}{57948} \\
 \quad = 145.121 \\
 \\
 \text{G7:} \quad 174.1 \times \frac{2551}{317390} + 245.6 \times \frac{6477}{317390} + 178.4 \times \frac{19626}{317390} \\
 \quad + 213.6 \times \frac{5229}{317390} + 168.5 \times \frac{3743}{317390} + 181.5 \times \frac{1090}{317390} \\
 \quad + 186.3 \times \frac{297}{317390} + 148.3 \times \frac{1449}{317390} + 159 \times \frac{4802}{317390} \\
 \quad + 208.9 \times \frac{855}{317390} + 159.7 \times \frac{3956}{317390} + 188 \times \frac{1026}{317390} \\
 \quad + 178 \times \frac{962}{317390} + 209.7 \times \frac{2909}{317390} + 175.1 \times \frac{2233}{317390}
 \end{array}$$

+	215.9	$\times \frac{1460}{317390}$	+	204.2	$\times \frac{1294}{317390}$	+	219.7	$\times \frac{1750}{317390}$
+	205.7	$\times \frac{2902}{317390}$	+	213.6	$\times \frac{5702}{317390}$	+	200.6	$\times \frac{1548}{317390}$
+	215.6	$\times \frac{1751}{317390}$	+	178.7	$\times \frac{2283}{317390}$	+	243.5	$\times \frac{1685}{317390}$
+	237.3	$\times \frac{967}{317390}$	+	246.8	$\times \frac{600}{317390}$	+	226.9	$\times \frac{3738}{317390}$
+	232.6	$\times \frac{1205}{317390}$	+	237.2	$\times \frac{2329}{317390}$	+	236.8	$\times \frac{3432}{317390}$
+	214	$\times \frac{1807}{317390}$	+	216.2	$\times \frac{461}{317390}$	+	218.9	$\times \frac{1107}{317390}$
+	197.3	$\times \frac{9268}{317390}$	+	200.8	$\times \frac{12865}{317390}$	+	201.2	$\times \frac{4132}{317390}$
+	215.8	$\times \frac{1849}{317390}$	+	210.6	$\times \frac{3937}{317390}$	+	248.1	$\times \frac{5450}{317390}$
+	229.7	$\times \frac{4899}{317390}$	+	207.1	$\times \frac{10578}{317390}$	+	200.6	$\times \frac{4417}{317390}$
+	201.9	$\times \frac{2648}{317390}$	+	197.3	$\times \frac{6278}{317390}$	+	203.8	$\times \frac{7454}{317390}$
+	190.3	$\times \frac{1280}{317390}$	+	201.6	$\times \frac{7737}{317390}$	+	224.4	$\times \frac{823}{317390}$
+	212.6	$\times \frac{2923}{317390}$	+	205.7	$\times \frac{4294}{317390}$	+	175.4	$\times \frac{2222}{317390}$
+	180	$\times \frac{1947}{317390}$	+	194	$\times \frac{3601}{317390}$	+	181.1	$\times \frac{1027}{317390}$
+	226	$\times \frac{3265}{317390}$	+	192.4	$\times \frac{5170}{317390}$	+	203.8	$\times \frac{496}{317390}$
+	204.6	$\times \frac{1269}{317390}$	+	267.3	$\times \frac{9710}{317390}$	+	204.7	$\times \frac{31781}{317390}$
+	156.2	$\times \frac{17032}{317390}$	+	195.3	$\times \frac{5714}{317390}$			
+	102.4	$\times \frac{2227}{317390}$	+	93.1	$\times \frac{3002}{317390}$	+	102.2	$\times \frac{3235}{317390}$
+	86.6	$\times \frac{363}{317390}$	+	97	$\times \frac{706}{317390}$	+	35.2	$\times \frac{25479}{317390}$
+	102.2	$\times \frac{2592}{317390}$	+	103.8	$\times \frac{3148}{317390}$	+	96.6	$\times \frac{5607}{317390}$
+	119.5	$\times \frac{883}{317390}$	+	96.9	$\times \frac{1577}{317390}$	+	104	$\times \frac{1279}{317390}$
=	177.608							

Source: Japan Statistical Yearbook 1982, Table 299

Annual average Earnings by Occupational Groupings for Japan,
1980:

	<u>Y</u>	<u>month</u>	<u>unit</u>	<u>Exchange Rate</u>	<u>US \$</u>
G3:	151.283	× 12	× 1000	+ 226.70	= 8007.92
G4:	128.005	× 12	× 1000	+ 226.70	= 6775.74
G6:	145.12	× 12	× 1000	+ 226.70	= 7681.75
G7:	177.608	× 12	× 1000	+ 226.70	= 9401.40

Utilizing the available data, the wage and salary income by Group 1 is derived from the comparison of each of wage rates by ten occupations belong to the group in the Yearbook with each of those by the corresponding occupations in the United States Census.

G1: Comparison of the wages of Group 1 between Japan and the U.S.

Japan		U. S.	
(1980)		1979	(1980)
¥ 1,000 *	(US \$) **	US \$	(Δ 10.83%) ***

Male:

1. System engineers	1. Industrial & Mechanical engineering technician
228 (12,069)	19,363 (21,460)
2. Programmers	2. Computer programmer
200.7 (10,624)	17,967 (19,913)
3. Operator	3. Computer equipment operator
174.1 (9,216)	14,203 (15,741)
4. Chemical analysts	4. Other engineering and science technician
202.5 (10,719)	17,029 (18,873)

5. Pharmacists	215.2 (11,391)	5. Other health assessment & treating occupations	18,522 (20,528)
6. Medical X-ray technicians	220 (11,645)	6. Other health technicians	13,973 (15,486)

Female:

7. Nurses-	189.8 (10,047)	7. R.N.	11,520 (12,768)
8. Assistant nurses	149.6 (7,919)	8. Licensed practical nurses	8,025 (8,894)
9. Kindergarten teachers	126.2 (6,680)	9. Teacher	10,451 (11,583)
10. Nursery school teachers	127.6 (6,754)	10. Teacher	10,451 (11,583)

* Average monthly earnings

** Annual average earnings converted to US dollars
(\$ = ¥ 1000 × 12 ÷ 226.7)

*** Parentheses provide the figures augmented by 10.84% .

w^{JAP} / w^{US} :	1.	0.562
	2.	0.534
	3.	0.585
	4.	0.568
	5.	0.555
	6.	0.752
	7.	0.787
	8.	0.89
	9.	0.577
	10.	0.583

Average wage ratio = 0.639

Lower bound ratio = 0.534

Upper bound ratio = 0.89

Wage rate by Group 1 in Japan : 17,403 × 0.639 = 11,121

For groups 2 and 5, we use aggregate wage rates in Japan and the United States derived by Jorgenson and Kuroda (1990). Table 1.5 in Jorgenson and Kuroda (1990) shows the comparison of trend of labour input prices between the United States and Japan:

Labour Input Price Index		
<hr/>		
US	:	2.21758
JAP	:	1.33755

The figures in the following parentheses are the US average earnings by corresponding groups in 1980.

$$\begin{aligned} \text{G2: } & 1.33755/2.21758 \times (23817) = 14365 \\ \text{G5: } & 1.33755/2.21758 \times (10674) = 6438 \end{aligned}$$

APPENDIX H

Math CAD Program

Origin = 1 Sets the origin = 1 (not 0)

PRNCOLWIDTH := 7 Column width of the WRITEPRN function = 7

First read input vectors and matrices. Since simultaneous access is limited, we combine several vectors and matrices in order to reduce the number of files. After reading the files we decompose and use them appropriately.

U01(26×13) + U02(26×13) + V01(26×13) + V02(26×13) is first read from file UV0 and then divided into appropriate matrices and scaled.

UV0 := READPRN(UV0)

i := 1 .. 26

j := 1 .. 13

U_{1,j} := UV0_{1,j} (0.1)

U_{1,j+13} := UV0_{1+26,j} (0.1)

V_{1,j} := UV0_{1+52,j} (0.1)

V_{1,j+13} := UV0_{1+78,j} (0.1)

Next we read DBB (26×8) matrix

DBB := READPRN(DBB)

We then read a long column vector which is composed of the following vectors: X (26×1), DIG (26×1), M (26×1), TT (26×1), WM (8×1), PP (3×1)

```

SUMvtr  := READPRN(SUMvtr)

k       := 1 .. 8

n       := 1 .. 3

Xi     := SUMvtri

DIGi   := SUMvtri+26

Mi     := SUMvtri+52

TTi    := SUMvtri+78

WMk    := SUMvtrk+104

PPn    := SUMvtrn+112

```

All the input vectors and matrices are read from three files UVO.PRN, DBB.PRN and SUMvtr.PRN and then partitioned appropriately.

Now, actual calculation begins

```

m       := 1 .. 26

XHi,m  := δ(i,m) Xi           XH = diag(X)

XHI     := XH-1               XHI = inv(XH)

BB      := XHI · UT

CB      := XHI · V

CBI     := CB-1               CBI = inv(CB)

GBB     := CBI · BB

```

Since some elements are less than zero even though they are close to zero (probably due to precision problem), we convert those elements into zero.

```

GBBi,m := if [ GBBi,m > 0, GBBi,m, 0 ]

B       := U · XHI

Z       := B · X + DIG

MTHETAi := 1 -  $\frac{-M_i}{Z_i}$            MTHETA(i) = 1 - THETA(i)

```

```

MTHETAHi,m :=  $\delta(1,m) \cdot MTHETA_1$ 
I          := identity(26)
LAMBDA BB  := (I - GBB)-1
GBT        := MTHETAH · GBB          MTHETAH = I - THETAH
LAMBDA BT  := (I - GBT)-1
LAMBDA BTi,m := if [ LAMBDA BTi,m > 0, LAMBDA BTi,m, 0 ]
DBT        := CBI · DBB
DBTi,k      := if [ DBTi,k > 0, DBTi,k, 0 ]

```

We then partition the vectors and matrices before the final calculation of the results.

```

ii        := 1 .. 23
mm        := 1 .. 23
TPTn      := TTn                n = 1 .. 3
TSTii     := TTii+3
GSPBTii,n := GBTii+3,n
DSMBTii,k := DBTii+3,k          k = 1 .. 8
LSSTii,mm := LAMBDA BTii+3,mm+3
LSSBii,mm := LAMBDA BBii+3,mm+3

```

Finally, the results are computed using the partitioned matrices and vectors.

```

FIRST TERM := TSTT · LSST · DSMBT · WM
SECOND TERM := TSTT · LSST · GSPBT · PP
THIRD TERM  := TPTT · PP
TOTAL       := FIRST TERM + SECOND TERM + THIRD TERM

```

In order to use LOTUS to print the intermediate and final results, we use WRITEPRN function to write vectors and matrices into DOS files.


```
WRITEPRN(GBB)      := GBB
WRITEPRN(LAMBDABB) := LAMBDABB
WRITEPRN(GBT)      := GBT
WRITEPRN(LAMBDABT) := LAMBDABT
WRITEPRN(DBT)      := DBT

WRITE(RESULT)      := FIRST TERM
APPEND(RESULT)      := SECOND TERM
APPEND(RESULT)      := THIRD TERM
APPEND(RESULT)      := TOTAL
```

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